JAPANESE [JP,2003-152603,A]

CLAIMS DETAILED DESCRIPTION TECHNICAL FIELD PRIOR ART EFFECT OF THE INVENTION TECHNICAL PROBLEM MEANS DESCRIPTION OF DRAWINGS DRAWINGS WRITTEN AMENDMENT

[Translation done.]

CLAIMS

[Claim(s)]
[Claim 1] It is the turbo receiving approach of receiving the signal from the transmitter of two or more integer N individuals, and is the input signal rm of one or more integers [M]. From a known signal, the channel value hmn (q) and the channel matrix H are calculated. Here m= 1, —, M, n= 1, —, N, q= 0, —, Q−1, and Q are several N prior information lambda 2 on the multi-pass of each transmitted electric wave. [bn (k)] to soft decision transmitting symbol b'n It asks for (k). k is the discrete time-of-day and channel value hmn (q) and soft decision transmitting symbol b'n here. Using (k), interferent component H−B' (k) to the sending signal of the n−th transmitter is calculated, and it is here, and is [Equation 1].

$$H=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & \ddots & \\ 0 & & H(0) & \cdots H(Q-1) \end{bmatrix}$$

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix}$$

B' (k) =[b'T (k+Q −1) — b'T (k) — b'T(k−Q +1)]Tb'(k+q) =[b'1 (k+q) b'2 — (k+q) b'N (k+q)]Tq=Q −1 .... −Q+1 It is b'(k) =[b'1 at q!=0. (k) — 0 — b'N [(k)] T The number of the zero of the element of b' (k) is n in q= 0.] [—] It asks for vector y' (k). T — a transposed matrix — it is — this interferent component H−B' (k) — from receiving vector y (k) — deducting — difference — here — y — (— k —) — = — [— rT — rT (k+Q −1) — (k+Q −2) — rT — (— k —) —] — Tr — (— k —) — = — [— r — one — (— k —) — r — two — (— k —) — rM — (— k —) —] — T — a channel — a matrix — H — or — a reference sign — using — difference — adaptation filter factor wn to the input signal of the sending signal from the n−th transmitter which removes the residual interferent component in vector y' (k) It asks for (k). difference — vector y' (k) — the above-mentioned adaptation filter factor wn as the input signal [as opposed to / carry out filtering by (k) and / the sending signal from the n−th transmitter] by which interference removal was carried out — a logarithm — the turbo receiving approach characterized by obtaining a likelihood ratio.
[Claim 2] the covariance matrix of the noise component in the receiving vector y (k) — U — carrying out — the soft decision transmitting symbol b'n(k) above-mentioned channel matrix H −− using — the above-mentioned adaptation filter wn (k) wn (k) =(HG(k) HH+U)−1h — here G(k) =diag [D(k+Q −1) —D(k) —D (k−Q +1)]
D(k+q) =diag[1−b'21 (k+q), —, 1−b' 2 n (k+q)
— and 1−b' 2 1(k+q)] q=Q−1 — −Q+1 and q!=0 =diag[— 1−b' — 21 (k+q), —, 1, —, 1−b'N 2] (k+q) q= 0 — [Equation 2]

$$h=\begin{bmatrix} H_{1,(Q-1)\cdot N+n} \\ H_{2,(Q-1)\cdot N+n} \\ \vdots \\ H_{M,(Q-1)\cdot N+n} \end{bmatrix}$$

H1 and -(Q-1) N+n The turbo receiving approach according to claim 1 characterized by computing by the one-line (Q-1) N+n train component of the top Noriyuki train H.
[Claim 3] the turbo receiving approach of receiving the signal from the transmitter of two or more integer N individuals — it is — input signal rm of one or more integers [M] From a known signal, the channel value hmn (q) and the channel matrix H are calculated. m= 1, —, M, n= 1, —, N, q= 0, —, Q-1, and Q are several N prior information lambda 2 on the multi-pass of each transmitted electric wave here. [bn (k)] to soft decision transmitting symbol b'n It asks for (k). k is the discrete time-of-day and channel value hmn (q) and soft decision transmitting symbol b'n here. Using (k), interferent component H-B' (k) to the sending signal of the n-th transmitter is calculated, and it is here, and is [Equation 3].

$$H=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & & \ddots & \\ 0 & & H(0) & & \cdots H(Q-1) \end{bmatrix}$$

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix}$$

B' (k) =[b'T (k+Q -1) — b'T (k) — b'T(k-Q +1)]Tb'(k+q) =[b'1 (k+q) b'2 () k+q — b'N (k+q)]Tq=Q -1 .... -Q+1 It is b'(k) =[b'1 at q!=0. (k) — f (b'n (k)) — b'N [f (b'n (k)) of the element of b' (k) is the n-th in (k)]T q=0.] f ( ) — f(0) =0 and d — {— f (the function which makes a variable b'n (k) which fills b'n(k)}/d{b'n(k)} >=0 —) [—] It asks for vector y' (k). T — a transposed matrix — it is — this interferent component H-B' (k) — from receiving vector y (k) — deducting — difference — here — y — (— k —) — = — [— rT — rT (k+Q -1) — (k+Q -2) — rT — (— k —) —] — Tr — (— k —) — = — [— r — one — (— k —) — r — two — (— k —) — rM — (— k —) —] — T — a channel — a matrix — H — or — a reference sign — using — difference — adaptation filter factor wn to the input signal of the sending signal from the n-th transmitter which removes the residual interferent component in vector y' (k) It asks for (k). difference — vector y' (k) — the above-mentioned adaptation filter factor wn as the input signal [as opposed to / carry out filtering by (k) and / the sending signal from the n-th transmitter] by which interference removal was carried out — a logarithm — the turbo receiving approach characterized by obtaining a likelihood ratio.
[Claim 4] the covariance matrix of the noise component in the above-mentioned receiving vector y (k) — U — carrying out — soft decision transmitting symbol b'n the (k) above-mentioned channel matrix H — using — the above-mentioned adaptation filter wn (k) wn (k) =(HG(k) HH+U)-1h — here G(k) =diag [D(k+Q -1) —D(k) —D (k-Q +1)]
D(k+q) =diag[1-b'21 (k+q), —, 1-b' 2 n (k+q)
—, 1-b' 2 1(k+q)] q=Q -1 — by -Q+1 and q!=0 = diag[1-b'21 (k+q), —, 1-b'2n-1(k)1+2E[f (b'n(k)] +E[f (E[ ] expresses an average with b'n(k)2], 1-b'2n+1(k), —, 1-b' 2 N(k+q)] q=0.))
[Equation 4]

$$h=\begin{bmatrix} H_{1,(Q-1)\cdot N+n} \\ H_{2,(Q-1)\cdot N+n} \\ \vdots \\ H_{M,(Q-1)\cdot N+n} \end{bmatrix}$$

H1 and -(Q-1) N+n The turbo receiving approach according to claim 3 characterized by computing by the one-line (Q-1) N+n train component of the top Noriyuki train H.

[Claim 5] The above-mentioned adaptation filter wn The turbo receiving approach according to claim 2 or 4 characterized by performing the inverse-matrix operation in count of (k) using the lemma of an inverse matrix.

[Claim 6] The turbo receiving approach given in claim 1 thru/or any of 5 they are. [which is characterized by setting the covariance matrix U of the noise component within the receiving vector y (k) to sigma2I which can be found from variance sigma2 and the unit matrix of Gaussian distribution]

[Claim 7] The covariance matrix U of the noise component within the above-mentioned receiving vector y (k) Above-mentioned receiving vector y (k), The above-mentioned presumed channel matrix H is used. U^= — sigmak=0 Tr (y(k)-H^-B (k)) and (y(k)-H^-B (k)) HB (k) =[bT —(k+Q -1) bT (k) —bT] (k-Q +1) =[Tb(k+q)] [b1 —(k+q) bN] (k+q) T (q=-Q+1 — Q-1)
Tr is the turbo receiving approach given in claim 1 thru/or any of 5 they are. [which is characterized by considering as the die length of a reference sign]

[Claim 8] The turbo receiving approach given in claim 2 thru/or any of 7 they are. [which is characterized by approximating Above D (k+q) with 0 and approximating Above D (k) by diag (0, --, [1, —, 0])]

[Claim 9] It is the turbo receiving approach of receiving the signal from the transmitter of two or more integer N individuals, and is the input signal rm of one or more integers [M]. From a known signal, the channel value hmn (q) and the channel matrix H are calculated. Here m= 1, —, M, n= 1, —, N, q= 0, —, Q-1, and Q are several N prior information lambda 2 on the multi-pass of each transmitted electric wave. [bn (k)] to soft decision transmitting symbol b'n It asks for (k). k is the discrete time-of-day and channel value hmn (q) and soft decision transmitting symbol b'n here. Using (k), interferent component H-B' (k) to the sending signal of the n-th transmitter is calculated, and it is here, and is [Equation 5].

$$H=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & & \ddots & \\ 0 & & H(0) & & \cdots H(Q-1) \end{bmatrix}$$

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \\ & & \end{bmatrix}$$

B' (k) =[b'T (k+Q -1) — b'T (k) — b'T(k-Q +1)]Tb'(k+q) =[b'1 (k+q) b'2 — (k+q) b'N (k+q)]Tq=Q - 1 .... -Q+1 It is b'(k) =[b'1 at q!=0. (k) — 0 — b'N [(k)] T The number of the zero of the element of b' (k) is n in q= 0.] [—] It asks for vector y' (k). T — a transposed matrix — it is — this interferent component H-B' (k) — from receiving vector y (k) — deducting — difference — here — y — (— k —) — = — [— rT — rT (k+Q -1) — (k+Q -2) — rT — (— k —) —] — Tr — (— k —) — = — [— r — one — (— k —) — r — two — (— k —) — rM — (— k —) —] — T — reception — a vector — y — (— k —) — inside — a noise — a component — a covariance

matrix — As sigma2 I which can be found from distributed sigma2 of Gaussian distribution, and a unit matrix I, it is [Equation 6].

$$h = \begin{bmatrix} H_{1,(Q-1)\cdot N+n} \\ H_{2,(Q-1)\cdot N+n} \\ \vdots \\ H_{M\cdot Q,(Q-1)\cdot N+n} \end{bmatrix}$$

adaptation filter coefficient wn which was boiled and was determined more difference — as the input signal from which filtering of vector y' (k) was carried out, and the interference to the sending signal from the n-th transmitter was removed — a logarithm — the turbo receiving approach characterized by obtaining a likelihood ratio.

[Claim 10] the turbo receiving approach of receiving the signal from the transmitter of two or more integer N individuals — it is — input signal rm of one or more integers [M] From a known signal, the channel value hmn (q) and the channel matrix H are calculated. m= 1, —, M, n= 1, —, N, q= 0, —, Q-1, and Q are several N prior information lambda 2 on the multi-pass of each transmitted electric wave here. [bn (k)] to soft decision transmitting symbol b'n It asks for (k). k is the discrete time-of-day and channel value hmn (q) and soft decision transmitting symbol b'n here. Using (k), interferent component H-B' (k) to the sending signal of the n-th transmitter is calculated, and it is here, and is [Equation 7].

$$H = \begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & \ddots & \vdots \\ 0 & & H(0) & \cdots H(Q-1) \end{bmatrix}$$

$$H(q) = \begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix}$$

B' (k) =[b'T (k+Q -1) — b'T (k) — b'T(k-Q +1)]Tb'(k+q) =[b'1 (k+q) b'2 () k+q — b'N (k+q)]Tq=Q -1 .... It is f (b'n (k) is the n-th) of the element of b' (k) at -Q+1 (k)]T q=0. It is b'(k) =[b'1 at q!=0. (k) — f (b'n (k)) — b'N f ( ) — f(0) =0 and d — {— f (the function which makes a variable b'n (k) which fills b'n(k)}/d{b'n(k)} >=0 —) [—] It asks for vector y' (k). T — a transposed matrix — it is — this interferent component H-B' (k) — from receiving vector y (k) — deducting — difference — here — y — (— k —) — = — [— rT — rT (k+Q -1) — (k+Q -2) — rT — (— k —) —] — Tr — (— k —) — = — [— r — one — (— k —) — r — two — (— k —) — rM — (— k —) —] — T — reception — a vector — y — (— k —) — inside — a noise — a component — a covariance matrix — As sigma2 I which can be found from distributed sigma2 of Gaussian distribution, and unit-matrix I </FONT>, it is [Equation 8].

$$h = \begin{bmatrix} H_{1,(Q-1)\cdot N+n} \\ H_{2,(Q-1)\cdot N+n} \\ \vdots \\ H_{M\cdot Q,(Q-1)\cdot N+n} \end{bmatrix}$$

adaptation filter coefficient wn which was boiled and was determined more difference — as the input signal from which filtering of vector y' (k) was carried out, and the interference to the

sending signal from the n-th transmitter was removed — a logarithm — the turbo receiving approach characterized by obtaining a likelihood ratio.
[Claim 11] It is the turbo receiving approach of receiving the sending signal from the transmitter of two or more integer N individuals. The channel value which is the transmission characteristic of an input signal is calculated from the input signal of one or more integers [M], and a known signal. Presume a soft decision transmitting symbol from the prior information on N individual, respectively, and the sending signal of N individual is divided into L sending-signal groups (L<=N) which consist of 1 thru/or two or more sending signals, respectively. L identification signals which removed the interference from other sending-signal groups about each of that sending-signal group using the channel matrix which consists of a soft decision transmitting symbol and a channel value, respectively, The transmission characteristic of the identification signal and the channel information after the identification which corresponds, respectively are searched for. About each class of these L sets of identification signals and channel information, make the identification signal group into an input signal, make channel information into a channel value, and when the configuration sending signal is plurality Divide the configuration sending signal into two or more sending-signal groups which consist of further 1 thru/or two or more sending signals, and a soft decision transmitting symbol is used. The channel information after the identification signal which removed the interference from other sending-signal groups about the sending-signal group, respectively, and identification is searched for. When the number of configuration sending signals is one, the identification signal and channel information, and a soft decision transmitting symbol are used. Until it removes interference by the multi-pass of the sending signal itself and the configuration sending signal of all identification signals becomes one piece The above-mentioned division, Repeat interference removal and generation of the channel information after identification, and the identification signal which finally removed interference by the multi-pass of itself about each sending signal is searched for. Or the turbo receiving approach characterized by searching for the identification signal which removed the between [sending signals] interference, and an own intersymbol interference for every configuration sending signal of the identification signal about the group of the above-mentioned identification signal and its channel information.
[Claim 12] About each above-mentioned sending-signal group, a soft decision transmitting symbol and a channel are used. Generate the interference replica from other sending-signal groups, respectively, deduct an interference replica from an input signal, respectively, and a differential signal is searched for, respectively. Search for the channel information after the filter shape for interference remainder component removal, and the above-mentioned identification for every differential signal from the above-mentioned channel value and a soft decision transmitting symbol, and filtering of the differential signal which corresponds by the filter shape for interference remainder component removal is carried out. The turbo receiving approach according to claim 11 characterized by acquiring the above-mentioned identification signal.
[Claim 13] the above-mentioned input signal r1 (k), —, rM (— k —) — from — reception — a vector — y — (— k —) — = — [— rT — rT (k+Q -1) — (k+Q -2) — rT — (— k —) —] — Tr — (— k —) — = — [— r — one — (— k —) — r — two — (— k —) — rM — (— k —) —] — T — [— —] — T a transposed matrix — front **** — asking — the above-mentioned transmission characteristic — the channel matrix H — carrying out — [Equation 9]

$$H=\begin{bmatrix} H(0) & \cdots & H(Q-1) & & 0 \\ & \ddots & & \ddots & \\ 0 & & H(0) & \cdots & H(Q-1) \end{bmatrix}$$

H (q) = [h1 (q) —hN (q)]
hn The number of (q) =[h1n(q) —hMn(q)] Tm=1, —, M, n= 1, —, N, and multi-passes is set to Q. It is q= 0, —, Q-1, and hmn (q) is an input signal rm. It is the channel value of the pass q from the n-th transmitter contained. They are eye **** and the above-mentioned soft decision transmitting symbol b'n It is referred to as (k). The configuration about the one above-mentioned sending-signal group The 1st thru/or the Uth sending signal, U is a becoming integer N>U>=1 and calculates the interference replica from a sending-signal group besides the above by H-

B' (k) here. It is B'(k) =[b'T here. — (k+Q −1) b'T (k) — b'T(k−Q +1)]Tb'(k+q) =[b'1 (k+q) b'2 — (k+q) b'n — (k+q) b'N (k+q)]T : It is b'(k+q) =[0 at q=Q −1 and —1. — 0 bu+1' (k+q) — by b'N] (k+q) T:q=0, —, −Q+1 the number of the elements of zero in b' (k+q) — U pieces — it is — this interference replica H−B' (k) — from above-mentioned receiving vector y (k) — subtracting — the above — difference — vector y'g The turbo receiving approach according to claim 12 characterized by asking for (k).

[Claim 14] The turbo receiving approach according to claim 11 or 12 characterized by making into smallness the number of the multi-passes in the case of the interference removal processing which the identification signal received previously in case interference removal is further performed to the above-mentioned identification signal and its channel information.

[Claim 15] the above-mentioned input signal r1 (k), —, rM (— k —) — from — reception — a vector — y — (— k —) — = — [— rT — rT (k+Q −1) — (k+Q −2) — rT — (— k —) —] — Tr — (— k —) — = — [— r — one — (— k —) — r — two — (— k —) — rM — (— k —) —] — T — [— —] — T a transposed matrix — front **** — asking — the above-mentioned transmission characteristic — the channel matrix H — carrying out — [Equation 10]

$$H=\begin{bmatrix} H(0) & \cdots & H(Q-1) & & 0 \\ & \ddots & & \ddots & \\ 0 & & H(0) & \cdots & H(Q-1) \end{bmatrix}$$

H (q) = [h1 (q) —hN (q)]

hn The number of (q) =[h1n(q) —hMn(q)] Tm=1, —, M, n= 1, —, N, and multi-passes is set to Q. It is q= 0, —, Q−1, and hmn (q) is an input signal rm. It is the channel value of the pass q from the n-th transmitter contained. They are eye **** and the above-mentioned soft decision transmitting symbol b'n It is referred to as (k) and the configuration is made into the 1st thru/or the Uth sending signal about the one above-mentioned sending-signal group. U is a becoming integer N>U>=1 and sets to Q'<Q the number of the multi-passes in the interference removal processing to the identification signal by which interference removal processing was carried out to this sending-signal group here. The interference replica from a sending-signal group besides the above is calculated by H−B' (k). It is B'(k) =[b'T here. — (k+Q −1) b'T (k) — b'T () k−Q+1] Tb'(k+q) =[b'1 (k+q) b'2 — (k+q) b'n — (k+q) b'N (k+q)]T : It is b'(k+q) =[0 at q=Q −1 and —1. — 0 b'u +1 (k+q) — The number of elements of zero in b'N](k+q) T:q=0, —, −Q'+1b' (k+q) is U pieces. b'(k+q) =[b'1 —(k+q) b'n —(k+q) b'N] (k+q) T : This interference replica H−B' (k) is subtracted from above-mentioned receiving vector y (k). q=Q', —, −Q+1 — difference — vector y'g (k) — **** — the turbo receiving approach according to claim 14 characterized by things.

[Claim 16] The turbo receiving approach given in claim 1 thru/or any of 15 they are. [which makes a reference sign a known signal and the transmitting coding symbol hard decision output obtained by the last processing in the repeat processing 2nd after turbo reception, and is characterized by calculating the above-mentioned channel matrix using this reference sign and input signal]

[Claim 17] The turbo receiving approach according to claim 16 characterized by the probability under transmitting coding symbol hard decision output obtained by the last processing using for count of the above-mentioned channel matrix by making the thing beyond a predetermined value into a reference sign.

[Claim 18] prior information lambda 2 on the above-mentioned N individual the logarithm as an input signal [as opposed to / obtain [bn (k)] from the transmitter of the above-mentioned N individual, and the corresponding decoder of N individual, and / the n-th above-mentioned sending signal] by which interference removal was carried out — the turbo receiving approach given in claim 1 thru/or any of 17 they are. [which is characterized by supplying a likelihood ratio to a corresponding decoder]

[Claim 19] The sending signal of the above-mentioned N individual is a signal transmitted with the transmitter of N individual as a sequence of juxtaposition of one information sequence of N individual, respectively. Prior information lambda 2 on the above-mentioned N individual [bn (k)] is the prior information lambda 2 on one decoder. Serial-parallel conversion of [the b (j)] is

carried out. the logarithm of N individual as an input signal to the sending signal of the above-mentioned N individual by which interference removal was carried out — the turbo receiving approach given in claim 1 thru/or any of 17 they are. [which is characterized by carrying out juxtaposition-serial conversion of the likelihood ratio, and supplying the above-mentioned decoder]

[Claim 20] It is m= 1, —, the channel presumption machine that M each input signal rm and the reference sign of a known signal are inputted, and calculates the channel value hmn (q) and the channel matrix H, and here here, and is [the input-signal generation section which receives the signal from the transmitter of two or more integer N individuals and which is a turbo receiver and obtains the input signal rm of one or more integers / M /, and] [Equation 11].

$$H=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & \ddots & \\ 0 & & H(0) & \cdots H(Q-1) \end{bmatrix}$$

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix}$$

n= 1, —, N each input signal rm it inputs — having — receiving vector y(k) =[rT rT (k+Q -1) — (k+Q -2) rT (k)] Tr(k) =[— r1 (k) r2 (k) —rM — (k) —] — T — here — k — discrete time of day and Q — the number of the multi-passes of each transmitted electric wave — q= 0, —, Q-1, and [ ]T The receiving vector generation section which generates ** showing a transposed matrix, The prior information on N individual is inputted and it is soft decision transmitting symbol b'n. The soft decision symbol generation section which generates (k), Each soft decision transmitting symbol b'1 (k) - b'N (k) is inputted. Interference replica vector B'(k) =[b'T(k+Q -1) - -b'T(k) —b'T(k-Q +1)] =[Tb'(k+q)] [b'1 b(k+q) '2 —(k+q) b'N] (k+q) Tq=Q -1 to the n-th sending signal, —, -Q+1 q!=0 — b'(k) =[b'1 (k) —0 —b'N (k)] T — The replica vector generation section in which the zero of the element of b' (k) generate the n-th by q= 0, The filtering section which interference replica vector B' (k) is inputted as the channel matrix H, and calculates and outputs interferent component H-B' (k) to the input signal of the n-th sending signal, interferent component H-B' (k) and receiving vector y (k) inputs — having — difference — with the difference operation part which outputs vector y'(k) =y(k)-H-B' (k) the channel matrix H or a reference sign inputs — having — difference — with the filter factor presumption section which asks for the adaptation filter factor wn (k) to the input signal of the sending signal from the n-th transmitter from which the residual interferent component in vector y' (k) is removed Vector y' (k) and the above-mentioned adaptation filter factor wn (k) are inputted, and filtering is carried out to y' (k). difference — as the input signal to the sending signal from the n-th transmitter by which interference removal was carried out — a logarithm — the turbo receiver characterized by providing the adaptation filter section which obtains a likelihood ratio and is supplied to the n-th decoder.

[Claim 21] It is m= 1, —, the channel presumption machine that the decoder of MN individual, each input signal rm, and the reference sign of a known signal are inputted, and calculates the channel value hmn (q) and the channel matrix H, and here here, and is [the input-signal generation section which receives the signal from the transmitter of two or more integer N individuals and which is a turbo receiver and obtains the input signal rm of one or more integers / M /, and] [Equation 12].

$$H=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & \ddots & \\ 0 & & H(0) & \cdots H(Q-1) \end{bmatrix}$$

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix}$$

n= 1, --, N each input signal rm it inputs -- having -- receiving vector y(k) =[rT rT (k+Q -1) -- (k+Q -2) rT (k)] Tr(k) =[-- r1 (k) r2 (k) --rM -- (k) --] -- T -- here -- k -- discrete time of day and Q -- the number of the multi-passes of each transmitted electric wave -- q= 0, --, Q-1, and [ ]T The receiving vector generation section which generates ** showing a transposed matrix, The prior information on N individual is inputted and it is soft decision transmitting symbol b'n. The soft decision symbol generation section which generates (k), and (n= 1, --, N), Each soft decision transmitting symbol b'1 (k) - b'N (k) is inputted. Interference replica vector B'(k) =[b'T(k+Q -1) --b'T(k) --b'T(k-Q +1)] =[Tb'(k+q)] [b'1 b(k+q) '2 --(k+q) b'N] (k+q) Tq=Q - 1 to the sending signal from the n-th transmitter, --, -Q+1, q!=0 -- b'(k) =[b'1 (k) --f(b'n (k)) -- b'N (k)] T q=0 -- f (b'n (k)) of the element of b' (k) -- the n-th -- f ( ) is b'n which fills f(0) =0 and d{f(b'n (k))}/d{b'n (k)} >=0. The replica vector generation section which is the function which makes (k) a variable and generates **, The filtering section which interference replica vector B' (k) is inputted as the channel matrix H, and calculates and outputs interferent component H-B' (k) to the input signal of the sending signal from the n-th transmitter, interferent component H-B' (k) and receiving vector y (k) inputs -- having -- difference -- with the difference operation part which outputs vector y'(k) =y(k)-H-B' (k) the channel matrix H or a reference sign inputs -- having -- difference -- with the filter factor presumption section which asks for the adaptation filter factor wn (k) to the input signal of the sending signal from the n-th transmitter from which the residual interferent component in vector y' (k) is removed Vector y' (k) and the above-mentioned adaptation filter factor wn (k) are inputted, and filtering is carried out to y' (k). difference -- as the input signal to the sending signal from the n-th transmitter by which interference removal was carried out -- a logarithm -- the turbo receiver characterized by providing the adaptation filter section which obtains a likelihood ratio and is supplied to the n-th decoder.

[Claim 22] The input-signal generation section which receives a sending signal from the transmitter of two or more integer N individuals and which is a turbo receiver and generates the input signal of one or more integers [M], The channel presumption machine which the reference sign of the M above-mentioned input signals and known signals is inputted, and presumes the channel value which is the transmission characteristic, The identification signal which the M above-mentioned input signals and the prior information on the above-mentioned channel value N individual were inputted, and removed the interferent component by the sending signal of other transmitters for every sending signal of 1 thru/or two or more above-mentioned transmitters, The preceding paragraph equalizer which outputs two or more sets of the identification signal and the channel information after corresponding identification, The above-mentioned identification signal, the group of the channel information, and the configuration sending signal of the identification signal and corresponding prior information are inputted from the above-mentioned preceding paragraph equalizer, respectively. the mutual intervention of an intersymbol interference or this according to the multi-pass about each of the identification signal to a configuration sending signal, and other sending signals in the configuration signal -- removing -- a logarithm -- the turbo receiver possessing two or more latter-part equalizers which output a likelihood ratio.

[Claim 23] The input-signal generation section which receives a sending signal from the transmitter of two or more integer N individuals and which is a turbo receiver and generates the input signal of one or more integers [M], The channel presumption machine which the reference

sign of the M above-mentioned input signals and known signals is inputted, and presumes the channel value which is the transmission characteristic, The identification signal which the M above-mentioned input signals, and the above-mentioned channel values and the prior information on N individual were inputted, and removed the interferent component by the sending signal of other transmitters for every sending signal of 1 thru/or two or more above-mentioned transmitters, The preceding paragraph equalizer which outputs two or more sets of the identification signal and the channel information after corresponding identification, The above-mentioned identification signal, the group of the channel information, two or more sending signals that constitute the identification signal, and corresponding prior information are inputted from the above-mentioned preceding paragraph equalizer. The turbo receiver possessing two or more latter-part equalizers which output two or more sets of the identification signal which removed the interferent component by other other sending signals in the configuration sending signal, its identification signal, and the channel information after corresponding identification for two or more sending signals of every in the configuration sending signal of the plurality of the identification signal.

[Claim 24] A turbo receiver given in claim 20 thru/or any of 23 they are. [to which the hard decision transmitting symbol from a decoder is characterized by having the symbol storage section and a means to read a hard decision transmitting symbol from the symbol storage section last time in the repeat processing 2nd after turbo reception, and to supply a channel presumption machine as a reference sign last time by which updating storage is carried out by this]

[Claim 25] The turbo receiver according to claim 24 which a soft decision transmitting symbol is inputted and is equipped with the comparator in comparison with a threshold, and the selection section in which it is controlled by the output of the comparator and the soft decision transmitting symbol in a hard decision transmitting symbol stores the thing more than a threshold in the symbol storage section last time.

[Claim 26] the logarithm of N individual by which the output was carried out [above-mentioned] — a turbo receiver given in claim 20 thru/or any of 25 they are. [which is characterized by having the decoder of N individual with which a likelihood ratio is supplied, respectively, and acquiring the prior information on the above-mentioned N individual from the output of the decoder of the above-mentioned N individual]

[Claim 27] the logarithm of N individual by which the sending signal of the above-mentioned N individual is a signal transmitted from the transmitter of N individual, respectively as a sequence of juxtaposition of one information sequence of N individual, and the above-mentioned output is carried out — with the juxtaposition-serial transducer which changes a likelihood ratio into a serial sequence the logarithm of the above-mentioned serial sequence — a turbo receiver given in claim 20 thru/or any of 25 they are. [which is characterized by having the decoder into which a likelihood ratio is inputted, and the serial-parallel transducer which changes the prior information on the above-mentioned decoder into the juxtaposition sequence of N individual, and acquires the prior information on the above-mentioned N individual]

[Claim 28] The channel value as a line characteristic of an input signal is presumed from an input signal and the known signal as a reference sign. In the receiving approach of processing an input signal using the presumed channel value, performing decode processing to the processed signal, repeating processing and decode processing in which the channel value which carried out [above-mentioned] presumption to the same input signal was used, and performing them The turbo receiving approach characterized by determining the probability of the decoded hard decision information symbol from the value of the soft-decision information symbol, and a probability using it for the reference sign of next channel presumption of the hard decision information symbol beyond a predetermined value.

[Claim 29] The turbo receiving approach according to claim 28 characterized by including the process which calculates sigma2 I (sigma2 is the variance of Gaussian distribution and I is a unit matrix) for every above-mentioned repeat as a covariance matrix of the noise component within the receiving vector y (k).

[Claim 30] The covariance matrix U of the noise component within the input-signal vector y (k)

for every above-mentioned repeat Presumed channel matrix H^ and input-signal vector y (k) are used. U^=sigmak= -- 0 Tr (y(k)-H^-B (k)) and (y(k)-H^-B (k)) HB (k) =[bT --(k+Q -1) bT (k) -- bT] (k-Q +1) Tb(k+q) =[b1 --(k+q) bN] (k+q) T (q=-Q+1 -- Q-1)
For Tr, bN (k+q) is the reference sign which the above-mentioned known signal and the above-mentioned probability become from b1 from the hard decision information symbol beyond a predetermined value (k+q), and the turbo receiving approach according to claim 28 characterized by including the process which is the reference-sign length and calculates **.
[Claim 31] It is the turbo receiving approach given in any of claims 28-30 characterized by the repeat of processing and decode processing in which the channel value which carried out [above-mentioned] presumption was used being a repeat of the channel value which carried out [above-mentioned] presumption determining a linear equalization filter, processing an input signal with the linear equalization filter, and decoding the processed signal they are.
[Claim 32] The repeat of processing and decode processing of having used the channel value which carried out [above-mentioned] presumption is the turbo receiving approach of a publication [be / they / any of claims 28-30] of carrying out what it is the repeat of carrying out lake composition processing of compensating the phase rotation which is lake composition processing circles and each symbol received in the transmission line with the channel value which carried out [above-mentioned] presumption, and decoding the signal by which lake composition processing was carried out by the turbo decoder as the description.
[Claim 33] The repeat of processing and decode processing in which the channel value which carried out [above-mentioned] presumption was used is the turbo receiving approach given in any of claims 28-30 characterized by being the repeat of setting up the weight which determines antenna directional characteristics with the channel value which carried out [above-mentioned] presumption to an adaptive array antenna receive section, and decoding the output of an adaptive array antenna receive section by the turbo decoder they are.
[Claim 34] The turbo receiving approach according to claim 33 carried out [performing lake composition processing compensated with the channel value which carried out / above-mentioned / presumption of the phase rotation from which each symbol received the output of the above-mentioned adaptive array antenna receive section in the lake composition processing department in the transmission line, and supplying the signal by which lake composition processing was carried out to the above-mentioned turbo decoder, and] as the description.
[Claim 35] The channel value which is the line characteristic of an input signal is presumed from an input signal and the known signal as a reference sign. In the receiver which processes an input signal using the presumed channel value, performs decode processing to the processed signal, repeats processing and decode processing in which the channel value which carried out [above-mentioned] presumption to the same input signal was used, and performs them The means which the probability of the decoded hard decision information symbol determines whether to be beyond a predetermined value, and the value of the soft-decision information symbol determines by whether it is more than a threshold, The turbo receiver characterized by having the symbol storage section last time the updating storage of the contents of storage carried out by the hard decision information symbol determined are probable, and using the contents of storage of the symbol storage section last time as a reference sign of next channel presumption.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention is applied to mobile communication and relates the waveform distortion based on interference to the turbo receiving approach of having applied the turbo sign technique and of performing identification repeatedly, and its receiver.
[0002]
[Description of the Prior Art] The technical problem of a mobile phone service is [how] quality on the limited frequency, and it is in whether the system which can own many users is built. There is a multi-input multi-output (Multi-Input Multi-Output:MIMO) system as a means to solve such a technical problem. This system configuration as shown in drawing 3030 A From two or more transmitters S1-SN to this time of day Symbol c1(i) -cN(i) is transmitted on this frequency, respectively. These sending signals A MIMO receiver equipped with two or more antenna #1 - #M receives, and a MIMO receiver processes an input signal, presumes transmitting symbol c1(i) -cN(i) of each transmitters S1-SN, and outputs it to an output terminal Out1 - OutN separately as c1^ (i) - cN^ (i).
[0003] Examination about the concrete construction of the MIMO receiver in a MIMO system is not fully performed the place to current. the number of multi-passes with which N and the transmitted electric wave of each transmitter reach a MIMO receiver in the number of transmitters when performing the configuration of the MIMO receiver in a MIMO system based on a MLSE (maximum likelihood estimation) norm — the computational complexity of Q, then a MIMO receiver — 2(Q-1) N a digit — becoming — several transmitters — the computational complexity will become immense with the increment in N and the number Q of multi-passes. Moreover, when receiving that to which the information on a single user was transmitted as two or more parallel signals, much computational complexity is needed for separating each parallel signal with the increment in the number of multi-passes. Then, although this invention proposes the turbo receiving approach of two or more sequences signal with sufficient count effectiveness, it explains the turbo receiver to the existing single user which becomes origin of this invention first (one transmitter), i.e., 1 sequence sending signal.
[0004] turbo ****** for single users — the example of a configuration of the transmitter in this case and a receiver is shown in drawing 31 . In a transmitter 10, after coding of information sequence c (i) is performed by the encoder 11 and the interleave (rearrangement) of the coding output is carried out by INTARIBA 12, a carrier signal is modulated with a modulator 13 and the modulation output is transmitted. This sending signal is received by the receiver 20 through a transmission line (each channel of a multi-pass). Identification of a delay wave is performed by the ************ (SISO:Single-Input-Single-Output) equalizer 21 in a receiver 20. Generally an input signal is changed into baseband, and the input signal of that baseband is sampled on the frequency of 1 time or more of the frequency of the symbol signal of the information sequence of a sending signal, and the input of this equalizer 21 is changed into a digital signal, and is inputted into an equalizer 21 as an input signal of a digital signal.
[0005] Reception output [in / in the case of a single user, N= 1 is hit in drawing 30 A, and / each receiving-antenna #m (m= 1, 2, —, M)] rm (k) = sigmaq=0 Q-1 hm (q) -b(k-q)+vm (k) (1)

It can express. For m, an antenna index and h are [a user's (transmitter 1) transmitting symbol and vm (k) of a channel value (transmission-line impulse response: line characteristic) and b (k-q +1)] the thermal noise inside a receiver 20. And the output from all antenna #1-#M is expressed as a vector of a formula (2), and it is a formula (3).
r(k) = [r1'(k) r2 (k) --rM (k)] T (2)
= sigmaq=0 Q-1 H (q) -b(k-q +1) +v (k) (3)
A definition is given. here — v (k) = — [— v — one — (— k —) — v — two — (— k —) — vM — (— k —) —] — T — (4)
H (q) = [h1 (q) —hM (q)] T (5)
It comes out. Moreover, [ ] T A transposed matrix is expressed. Next, the following vectors and matrices are defined in consideration of several Q of a multi-pass (channel).
[0006]
y(k) ** [rT rT (k+Q -1) —(k+Q -2) rT (k)] T (6)
**H-b (k) +n (k) (7)
It is here and is [0007].
[Equation 13]

$$H=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & \ddots & \\ 0 & & H(0) & \cdots H(Q-1) \end{bmatrix} \qquad (8)$$

[0008] However, b(k-q) =[b(k+Q -1) b(k+Q -2) —b (k-Q +1)] T (9)
n (k) = [vT vT (k+Q -1) —(k+Q -2) vT (k)] T (10)
It comes out. the logarithm of the probability for r (k) which the top defined to be inputted into an equalizer 21, for this SISO equalizer 21 to be a linear equalization machine, and for each coding bit {b (i)} to be +1 as that identification output, and the probability which is -1 — a likelihood ratio lambda 1 (LLR:Log-LikelihoodRatio) is drawn.
[0009]
[Equation 14]

$$\Lambda_1[b(k)]=\log\frac{\Pr[b(k)=+1\,|\,y(k)]}{\Pr[b(k)=-1\,|\,y(k)]} \qquad (11)$$

$$\equiv \lambda_1[b(k)]+\lambda_2^p[b(k)] \qquad (12)$$

[0010] It comes out. It is lambda 1 here. [b (k)] is the external information and lambda2p which are sent to the consecutive decoder 24. [b (k)] is prior information given to an equalizer 21. a logarithm — likelihood ratio lambda 1 [b (k)] — prior information lambda 2 [b (k)] is subtracted with a subtractor 22, and is further supplied to the SISO channel decoder 24 through DEINTARIBA 23. this decoder 24 — a logarithm — a likelihood ratio lambda 2 and [0011]
[Equation 15]

$$\Lambda_2[b(i)]=\log\frac{\Pr[b(i)=+1\,|\,\lambda_1[b(i)],i=0,\cdots,B-1]}{\Pr[b(i)=-1\,|\,\lambda_1[b(i)],i=0,\cdots,B-1]} \qquad (13)$$

B：フレーム長

$$\equiv \lambda_2[b(i)]+\lambda_1^p[b(i)] \qquad (14)$$

[0012] It computes. It is lambda 2 here. [b (i)] is lambda2 p to an equalizer 21 in the case of a repeat. It is the external information given as [b (k)], and is lambda 1. [b (k)] is prior information lambda1 p to a decoder 24. It is given as [b (i)]. lambda 2 [b (i)] is lambda 1 with a subtractor 25. [b (i)] is subtracted and an equalizer 21 and a subtractor 22 are supplied through INTARIBA 26. Thus, identification and decode are performed repeatedly and improvement in an error rate is attained. Next, calculation of the linearity filter shape given to receiving vector y (k) as a detail of the equalizer 21 of the preceding paragraph is described. prior information lambda2 p of an equalizer 21 [b (k)] -- using -- soft decision symbol estimate b'(k) =tan h[— lambda2 p — [b

(k)]/2] (15)
It computes. And replica H-b[of an interferent component, i.e., an interferent component,] ' (k) is reproduced using this estimate and the channel matrix H, and it subtracts from an input signal. It is got blocked. y'(k) **y(k)-H-b' (k) (16)
= H-(b(k)-b' (k)) +n (k) (17)
It is here. b'(k) = [b'(k+Q -1) --0 --b' (k-Q +1)] T (18)
It calculates. Since replica H-b[of an interferent component] ' (k) is not necessarily an exact replica, it cannot remove an interferent component completely by the formula (16). Then, it asks for linearity filter factor w (k) which erases the remainder of an interferent component by the following MMSE (2nd [an average of] power error of the minimum) norms.
[0013]
w(k) =arg min ||wH (k) and y'(k)-b(k) ||2 (19)
H expresses conjugation transposition and is ||. || expresses a norm. It asks for w (k) which makes a formula (19) min. the following derivation of w (k) -- reference: -- it is indicated by Daryl Reynolds and Xiaodong Wang and "LowComplexity Turbo-Equalization for Diversity Channels" (http:/ee.tamu.edu/reynolds/). There is drastic reduction of computational complexity as main achievement matters of this technique. The computational complexity of the conventional MLSE mold turbo is 2Q-1. This technique is Q3 to having been proportional to order. It is stopped by order. In addition, wH (k) -y' (k) is the output of an equalizer 21 and is lambda 1 after this. [b (k)] is calculated, a decoder 24 is supplied through DEINTARIBA 23, and a decode operation is performed.
[0014] In order to perform identification processing in an equalizer 21, it is necessary to presume the channel value h (transmission-line impulse response) in a formula (1). Below, presumption of this channel value is described as channel presumption. Channel presumption is performed using the training sequence remembered to be the input signal of known training sequences, such as unique WORD sent to the head section in one frame. If the precision of channel presumption is bad, identification processing with an equalizer 21 will not be performed correctly. Although what is necessary is just to enlarge the rate that the training sequence in one frame occupies the precision of channel presumption to make it high, if it is made such, the transmission efficiency over original data will fall. Therefore, to make small the rate that the training sequence in one frame occupies, and to raise channel presumption precision is desired.
[0015] This has the same problem in the channel presumption in not only the receiver to the multi-sequence sending signal containing MIMO but a lake (RAKE) receiver, or the receiver which raises the probability of a decode result by decode processing repeatedly also in the receiver using an adaptive array antenna.
[0016]
[Problem(s) to be Solved by the Invention] The above-mentioned turbo receiver has the following technical problems.
- It is correspondence of only the sending signal of a single user (one set of transmitter), i.e., one sequence.
- In case an interferent component is reproduced, a channel value (matrix H) is required, and in case it is mounting, it is necessary to presume this.
The presumed error will degrade the effectiveness of identification repeatedly.
[0017] The purpose of this invention is to provide below with the turbo receiving approach which extended this object for reception to the receiver to two or more transmitting sequence signals, such as multiuser and ** single user juxtaposition transmission, and its receiver so that it may compensate these two points. Moreover, other purposes of this invention presume the channel value of an input signal from an input signal and the known signal as a reference sign. In the receiving approach of processing an input signal using the presumed channel value, performing decode processing to the processed signal, repeating processing and decode processing in which the channel value which carried out [above-mentioned] presumption was used to the same input signal, and performing them It is in offering the turbo receiving approach that a short paddle known signal can perform channel presumption with a sufficient precision comparatively, and its receiver.

[0018]
[Means for Solving the Problem] This 1st invention is the turbo receiving approach of receiving the sending signal of N sequence (N is two or more integers). M input signals rm (m= 1, --, M), From the known signal of N sequence, the channel value hmn (q), and (n= 1, --, N) are calculated. Prior information lambda 2 on N sequence acquired by decode It is based on [bn (k)] and is soft decision transmitting symbol b'n. It asks for (k). The channel value hmn (q) and soft decision transmitting symbol b'n Interferent component H-B' (k) made by sending signals other than the sending signal of the intersymbol interference which the sending signal of n sequence eye itself makes, and n sequence eye is calculated using (k), and it is here, and is [0019].
[Equation 16]

$$H=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & \ddots & \\ 0 & & H(0) & \cdots H(Q-1) \end{bmatrix}$$

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix}$$

[0020] B' (k) =[b'T (k+Q -1) -- b'T (k) -- b'T(k-Q +1)]Tb'(k+q) =[b'1 (k+q) b'2 -- (k+q) b'N (k+q)] Tq=Q -1 .... -Q+1 It is b'(k) =[b'1 at q!=0. (k) -- 0 -- b'N [(k)] T The zero of the element of (b'(k) by q= 0 n-ths),] Q is the number of the multi-passes of each sending-signal electric wave, q= 0, --, Q-1, and □. T expresses a transposed matrix.
[0021] this intersymbol-interference H-B' (k) -- from receiving vector y (k) -- deducting -- difference -- it asks for vector y' (k).
here -- y -- (-- k --) -- = -- [-- rT -- rT (k+Q -1) -- (k+Q -2) -- rT -- (-- k --) --] -- Tr -- (-- k --) -- = -- [-- r -- one -- (-- k --) -- r -- two -- (-- k --) -- rM -- (-- k --) --] -- T -- a channel -- a matrix -- H -- or -- a reference sign -- using -- difference -- for removing the residual interferent component in vector y' (k) adaptation filter coefficient wn to the input signal of the sending signal of n sequence eye (k) -- asking -- difference -- vector y' (k) -- the above-mentioned adaptation filter factor wn as the input signal [as opposed to / carry out filtering by (k) and / the sending signal of n sequence eye] by which interference removal was carried out -- the logarithm of n sequence -- a likelihood ratio is obtained. the logarithm of these N sequence -- it decodes using a likelihood ratio.
[0022] the -- two -- invention -- depending -- if -- the -- one -- invention -- setting -- q -- = -- zero -- a case -- b'(k) =[b'1 (k) --f(b'n (k)) --b'N (k)] Tb' (k) -- an element -- f (b'n (k) is the n-th) f ( ) is f(0) =0 and d{f (characterized by considering as the function which makes a variable b'n (k) which fills b'n (k)}/d{b'n (k)} >=0.). According to the 3rd invention, identification processing is divided into two or more steps, and is performed, and the latter part lessens the number of the sequences of an identification output.
[0023] According to this 4th invention, the channel value of an input signal is presumed from an input signal and the known signal as a reference sign. In the turbo receiving approach of processing an input signal using the presumed channel value, performing decode processing to the processed signal, repeating processing and decode processing in which the channel value which carried out [above-mentioned] presumption was used to the same input signal, and performing them The probability of the decoded hard decision information symbol is determined from the value of the soft-decision information symbol, and the probability uses it for the reference sign of next channel presumption of the hard decision information symbol beyond a predetermined value.
[0024]
[Embodiment of the Invention] The example of the MIMO structure of a system by which this invention is applied to 1st invention (1) drawing 1 is shown. Transmitter S1 of N individual of a transmitting side -- It sets to each of SN and is the information sequence c1. (i) -- cN (i) is

encoded by the encoder 11-1, —, 11-N, respectively. A modulator 13-1, —, 13-N are supplied as a modulating signal through INTARIBA 12-1, —, 12-N, a carrier signal is modulated by these modulating signals, and these coding output is a signal b1. (k), —, bN It is transmitted as (k). That is, sending signal b1 from Transmitters S1, —, SN (k), —, bN It is the case where (k) is the sending signal of N sequence.

[0025] Input-signal r (k) received by the multi-output receiver through the transmission line (channel) is inputted into the multi-output equalizer 31, and the signal received by the receiver is changed into baseband signaling, and the baseband signaling is sampled, for example with one half of the periods of the symbol period, is changed into a digital signal, and is inputted into an equalizer 31 as the digital signal. Moreover, let this digital signal be one or more integers [M]. For example, let the input signal from M antennas be the input signal of M digital signals. the logarithm of an equalizer 31 to N individual — likelihood ratio lambda 1 [b1 (k)], —, lambda 1 [bN (k)] is outputted. lambda 1 [b1 (k)], —, lambda 1 [bN (k)] is the prior information lambda 1, respectively. [b1 (k)], —, lambda 1 [bN (k)] is subtracted by the subtractor 22-1, —, 22-N, respectively. Through DEINTARIBA 23-1, —, 23-N, it is inputted into the ************ (SISO) decoder (channel decoder) 24-1, —, 24-N, respectively, and decodes. a decoder 24-1, —, the decode information sequence c'1 from 24-N (i), —, c'N while (i) is outputted — a logarithm — likelihood ratio lambda 2 [b1 (i)], —, lambda 2 [bN (i)] is outputted, respectively. lambda 2 [b1 (i)], —, lambda 2 [bN (i)] is lambda 1 by the subtractor 25-1, —, 25-N. [b1 (i)], —, lambda 1 [bN (i)] is subtracted, respectively. Furthermore, INTARIBA 26-1, —, 26-N are led, respectively, and it is lambda 2. [b1 (k)], —, lambda 2 The multi-output equalizer 31 and a subtractor 22-1, —, 22-N are supplied as [bN (k)], respectively.

[0026] Input signal rm from multiuser (two or more transmitters) (k), and (m= 1, —, M) are an input of an equalizer 31. rm (k) =sigmaq=0 Q-1 sigman=1 N hmn(q) and bn+(k-q) vm (k) (20)
It becomes what was added by the multiple user. q= 0, —, Q-1, and Q are y(k) **[rT rT (k+Q -1), if the number of the multi-passes of each transmitted electric wave and the same procedure as the case of a single user define vector y (k). — (k+Q -2) It is rT (k).
]T (21)
= H-B (k) +n (k) (22)
here — r(k) =[r1(k) —rM(k)] T [0027]
[Equation 17]

$$H=\begin{bmatrix} H(0) & \cdots H(Q-1) & 0 & \\ & \ddots & \ddots & \\ 0 & H(0) & \cdots & H(Q-1) \end{bmatrix} \qquad (23)$$

However, [0028]
[Equation 18]

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix} \qquad (24)$$

[0029]
B(k) =[bT (k+Q -1) — bT (k) — bT (k-Q +1)
]T (25)
b(k+q) = [b1 b(k+q)2 —(k+q) bN] (k+q) T q=Q -1, Q-2, —, -Q+1 (26)
It becomes. Next, in an interference removal step, it is assumed that the signal from the n-th user (transmitter) is a request now. the compound thing with interference which the signal of interference and the n-th user by the signal of users other than the n-th itself makes from this example using the soft decision symbol estimate of the signal from all users (transmitter), and the channel matrix (transmission-line impulse response value matrix) H, i.e., interference replica H-B', (k) — reproducing — as follows — y (k) to this interference replica — subtracting — difference — vector y' (k) is generated.

[0030]
y'(k) **y(k)-H-B' (k) (27)
= H-(B(k)-B' (k)) +n (k) (28)
It is here. B'(k) = [b'T(k+Q -1) —b'T(k) —b'T (k-Q +1)] T (29)
and — b'(k+q) =[b'1 b(k+q) '2 —(k+q) b'N] (k+q) T : q=Q -1, —, -Q+1, and q!=0 (30)
b'(k) = [b'1 (k) —0 —b'N (k)] T : q= 0 (31)
Zero in the element of b' (k) is the n-th. b'n (k) is b'n like a formula (15). It is the soft decision transmitting symbol estimate which calculated and calculated (k) =tan h [lambda2 [bn (k)]/2]. Vector B' (k) is the replica vector of an interference symbol.
[0031] Next, n-th filter factor wn for users for erasing the interference remainder based on the remainder of an interferent component, i.e., the incompleteness of interferent component replica H-B' (k), and the interferent component which the signal of the n-th self makes wn which makes the following formulas (32) min for (k) It asks for (k) by the MMSE (2nd [an average of] power error of the minimum) norm.
wn (k) =arg min ||wn H (k) and y'(k)-bn (k) ||2 (32)
The following actuation is the same as that of the case of a single user. That is, calculated wn (k) is used and it is wn H. (k) -y' (k) is calculated, DEINTARIBA 23-n is minded for the count result, and it is lambda 1. As [bn (i)], it inputs into decoder 24-n and a decode operation is performed.
[0032] It asks for filter (linear equalization) processing from the input signal rm by the above approach from a user 1 to N. As a result, the number of outputs of an equalizer 31 serves as N, and these outputs are decoded by each decoder 24-1, —, 24-N. The above is the escape for the multiuser (MIMO) of the turbo receiver for single users. From the above explanation, the example of a functional configuration of the multi-output equalizer 31 comes to be shown in drawing 2 . Receiving vector y (k) is generated by the receiving vector generation section 311, and M input signals rm (k) are supplied to the identification section 312-1 for every user - 313-N. Moreover, the channel matrix H calculated in the channel presumption machine 28 is supplied to the identification section 312-1 - 312-N. The prior information lambda 2 from each channel decoder 24-n [bn (k)] is inputted into the soft decision symbol presumption section 313, and it is soft decision transmitting symbol estimate b'n, respectively. (k) =tanh [lambda2 [bn (k)]/2] is calculated. The functional configuration and processing in the identification section 312-1 - 312-N are the same, are represented with the identification section 312-1, and are explained.
[0033] Furthermore, it is the estimate b'1 of a soft decision transmitting symbol. (k) - b'N (k) The interference replica vector generation section 314-1 is supplied, and it is the interference replica vector B'1 by formula (29) - (31). (k) is generated. this vector B'1 filtering of the (k) is carried out according to the channel matrix H in the filtering section 315-1 — having — interference replica component H-B' of that result — 1 (k) — the difference operation part 316-1 — receiving vector y1 it deducts from (k) — having — difference — vector y'1 (k) is generated.
[0034] The filter coefficient presumption section 317-1 is asked for the filter factor w1 the channel matrix H or for a reference sign being inputted so that it may mention later, and removing the remainder of said interferent component (k) at least. Filter factor w1 to which the channel matrix H from the channel presumption machine 28, covariance sigma2 of a noise component, the soft decision transmitting symbol b'1 from the soft decision symbol generation section 313-1 (k) - b'N (k) are inputted into the filter factor presumption section 317-1, and make a formula (32) min in this example (k) is called for by the 2nd [an average of] power error norm of the minimum. This filter factor w1 The concrete processing which asks for (k) is described later. the adaptation filtering section 318-1 — difference — vector y'1 (k) — filter factor w1 as the identification output of an input signal [as opposed to / it is processed by (k) and / the sending signal from a user 1] — lambda 1 [b1 (k)] is outputted.
[0035] Moreover, the procedure of the multi-input multi-output turbo receiving approach of the example of this invention mentioned above is shown in drawing 3 . They are input-signal r (k) and each training signal bn at step S1. Covariance sigma2 of the channel value hmn (q) and a noise component are calculated from (k). The channel matrix H is calculated from the channel value hmn (q) at step S2. Each prior information lambda 2 acquired by the last processing in turbo

reception at step S3 [bn (k)] to soft decision transmitting symbol estimate b'n (k) =tanh (lambda2 [bn (k)]/2) is calculated.
[0036] Receiving vector y (k) is generated from input-signal r (k) by step S4, and it is each soft decision transmitting symbol estimate b'n at step S5. (k) is used and it is interference replica vector B'n by formula (29) - (31). Interferent component replica H-B'n [as opposed to / generate (k) and / the input signal from the n-th transmitter at step S6] (k) is calculated. step S7 -- receiving vector y (k) to interferent component replica H-B'n (k) -- deducting -- difference -- vector y'n It asks for (k). Multiplier wn of a filter for the channel matrix H, and the soft decision transmitting symbol b'1 (k) - b'N (k) and covariance sigma2 of a noise component to remove the residual interference in the input signal from the n-th transmitter at step S8 It asks for (k) by the 2nd [an average of] power error norm of the minimum which makes a formula (32) min.
[0037] step S9 -- difference -- vector y'n (k) -- receiving -- filter factor wn filtering by (k) -- carrying out -- a logarithm -- likelihood ratio lambda 1 [bn (k)] is obtained. step S -- 10lambda1 [bn (k)] to prior information lambda 2 the day interleave after subtracting [bn (k)] -- giving -- further -- decode -- carrying out -- a logarithm -- likelihood ratio lambda 2 [bn (k)] is outputted. These step S4-S10 are processed being simultaneous or one by one about n= 1 - N. then -- if it investigates whether the count of decode of turbo reception, i.e., a count, turned into a predetermined number at step S11 and does not have a predetermined number -- step S12 -- a logarithm -- likelihood ratio lambda 2 [bn (k)] to external information lambda 1 [bn (k)] -- subtracting -- the result -- an interleave -- carrying out -- prior information lambda 2 In quest of [bn (k)], it returns to step S3. When decode is a count of predetermined at step S11, the decode result at that time is outputted at step S13.
[0038] Next, the channel presumption section 28 is described. Each input signal rm (k) can be expressed with a degree type.
rm (k) =sigmaq=0 Q-1 sigman=1 N hmn(q) and bn+(k-q) vm (k) (33)
The channel presumption section 28 is the value and Noise vm of hmn (q) of a channel value (transmission-line impulse response) in a formula (33). It asks for the mean power (**sigma2) of (k). Usually, a transmitting side inserts unique WORD (training signal) known with a receiver at the beginning of each transmitting frame, as shown in drawing 4 A, and the receiver presumes the channel value hmn (q) using RLS (recursive least square method) etc. by making the unique WORD (known signal) into a training sequence. the logarithm from each channel decoder 24-1, --, 24-N -- likelihood ratio lambda 2 [b1 (i)], --, lambda 2 About each of [bN (i)] If it is forward and negative about +1, -1, respectively Decode code-signal (transmitting coding symbol hard decision value) b1^ (i), It outputs as -- and bN^ (i) and these b1^ (i), --, bN^ (i) are repeatedly inputted into the channel presumption machine 28 through INTARIBA 27-1, --, 27-N. While input-signal r (k) is inputted into the channel presumption machine 28, unique WORD is inputted as a reference sign from the unique WORD storage section 29. The channel presumption machine 28 presumes each hmn (q) of a formula (33), and each value of sigma2 with the least square method based on the these-inputted signal. This presumption can be performed by the same technique as presumption of the impulse response in the case of presuming the impulse response of a transmission line and equalizing an input signal accommodative with an adaptation filter.
[0039] Thus, although the technique usually used uses a training sequence, it is necessary to make small the rate that the unique WORD in one frame occupies to gather a net transmission speed then, and the error of channel presumption increases. And the property of the repeat identification of the above [the error] will be degraded. Then, it is good to perform repeat presumption of a channel value as follows. The concept is shown in drawing 4 B. This also intends to presume the channel value repeatedly in each phase of repeat identification processing of the same input signal, i.e., repeat processing of turbo reception, and there is. That is, although a channel value is presumed to the information symbol sequence after unique WORD in the 1st time, using only unique WORD as a reference sign, an input signal is equalized using the presumed channel value and a transmitting symbol is presumed The symbol estimate (hard decision value) which used the unique WORD as a reference sign, performed channel

presumption and was obtained by the last decode processing before identification processing of the 2nd henceforth is also used as a reference sign, and performs channel presumption within [whole] a frame. In this case, it is good to use only the hard decision value judged to be probable as a reference sign not using all hard decision values. a hard decision — the logarithm from decoder 24-n — likelihood ratio lambda 2 If this is forward using [bn (i)] and it is +1 and negative, it is carried out by being referred to as -1. that time — the logarithm — likelihood ratio lambda 2 It can be said that the hard decision value is probable, so that the absolute value of [bn (i)] is large. for example, a logarithm — 1 when judging likelihood 0.3 to be 1 — a logarithm — 1 when judging likelihood 5 to be 1 is more nearly probable. Then, a threshold is used for below and it is the probable hard decision value bn. (i) is selected and how to perform channel presumption repeatedly using it is explained.

[0040] first — the logarithm from decoder 24-n — likelihood ratio lambda 2 [bn (i)] — using — soft decision value b'n of a symbol (i) — b'n [(i) =tan h[— lambda 2 — bn (i)]/2]

It asks by carrying out. this actuation — a logarithm — it is to standardize a likelihood value to 1. and for an absolute value not to exceed 1. Next, the threshold (between 0 and 1) is prepared beforehand and it is the soft decision value b'n. It is the hard decision value b^n to what has the larger absolute value of (i) than the threshold. (i) is saved, and this is repeated and it uses for channel presumption. For example, when a threshold is set as 0.9, it is soft decision value b'n. Absolute values are 0.9 or more hard decision value b^n among (i). (i) is sorted out. Hard decision value b^n sorted out since the threshold was as high as 0.9 Since it is thought that the probability of (i) is high, it is thought that the precision of repeat channel presumption performed using these goes up, but in order that the part and the number of symbols sorted out may decrease, it is thought that repeat channel presumption precision falls. That is, it is necessary to select the optimal threshold between 0 and 1. Hard decision value b^n sorted out when a threshold is temporarily set up with 1 as a supplement Since there is (no i), it will be said that channel presumption is not performed repeatedly. Then, although stated later, a threshold is set about to 0.2 to 0.8, and is performed.

[0041] Therefore, transmitting symbol estimate (hard decision value) b1^ to the 1st information symbol sequence (i), — and the symbol value judged to be probable with the threshold in bN^ (i) are memorized in the symbol storage section 32 last time as transmitting symbol estimate from the output of INTARIBA 27-1, —, 27-N. In the 2nd repeat identification decode processing of input-signal r (k) (input-signal r (k) is memorized in the storage section), perform channel presumption using unique WORD first, and an information symbol sequence is received further. The last symbol storage section 32 to presumed transmitting symbol hard decision estimate b^1 (i), —, b^N Read the symbol value judged that is probable in (i), and it inputs into the channel presumption machine 28. Channel presumption is performed, that is, channel presumption within [whole] a frame is performed, and it is the estimate hmn (q) and sigma2. It uses and the identification and the decode (transmitting symbol presumption) to input-signal r (k) are performed. Under the present circumstances, the contents of storage of the symbol storage section 32 are updated last time by the symbol value was alike and judged that is probable with the threshold in that presumed transmitting symbol. Channel presumption in the case of identification and the repeat of decode performs channel presumption within [whole] a frame like the following by presumption which uses unique WORD, and presumption using that judged that is probable in the last presumed transmitting symbol. Identification and decode (transmitting symbol presumption) are performed using the presumed channel, and the symbol storage section 32 is updated last time. In addition, in the symbol storage section 32, it is the transmitting symbol hard decision value b^1 from a decoder last time [this]. (i), —, b^N Renewal of direct storing of the symbol value judged that is probable with the threshold in (i) is carried out last time at the symbol storage section 32, and when using the storage symbol value of the symbol storage section 32 last time [this], you may make it input into the channel presumption machine 28 through INTARIBA 27-1, —, 27-N.

[0042] By doing in this way, by the repeat, the error of channel presumption can decrease, the precision of symbol presumption can improve, and the problem of property degradation by the channel presumption error in turbo identification can be solved. Thus, when performing channel

presumption in an information symbol sequence using a probable symbol hard decision value, the functional configuration shown in drawing 5 is added to each decoder 24-n. a logarithm -- likelihood ratio lambda 2 [bn (i)] is inputted into the soft decision value presumption section 241. b'n(i) =tanh (lambda2 [bn (i)]) is calculated, and it is transmitting symbol soft decision value b'n. (i) is presumed. This value b'n (i) is compared with threshold Th from the threshold setting section 243 by the comparator 242, and it is b'n. 0 is outputted for (i) by smallness from 1 and Th above Th. on the other hand -- a logarithm -- likelihood ratio lambda 2 [bn (i)] is inputted into the hard decision section 244. lambda 2 Symbol hard decision value b^n set to -1 if [bn (i)] was forward and it was +1 and negative (i) is outputted and it is this symbol hard decision value b^n. (i) With [a corresponding symbol soft decision value] a threshold [more than], it is outputted, the gate 245 being used as open, the symbol storage section 32 is supplied last time through INTARIBA 27-n in drawing 1 , and said symbol under storage is updated.

[0043] Moreover, the procedure of channel presumption also using a probable symbol hard decision value comes to be shown in drawing 6 . Channel presumption by input-signal r (k) and unique WORD is first performed at step S1, decode processing investigates whether it is the 1st time at step S2, and if it is the 1st time, steps S3-S10 under identification and decode processing, i.e., drawing 3 , will be processed using the presumed channel value hmn (q) at step S3. step S4 -- a logarithm -- likelihood ratio lambda 2 [bn (i)] -- receiving -- transmitting symbol hard decision processing -- carrying out -- hard decision value b^n (i) -- asking -- step S5 -- a logarithm -- likelihood ratio lambda 2 [bn (i)] -- receiving -- b'n (i) =tanh (lambda2 [bn (i)]/2) -- calculating -- transmitting symbol soft decision value b'n (i) is presumed. It is symbol soft decision value b'n at step S6. (i) is correspondence symbol hard decision value b^n by whether it is more than threshold Th. The probable thing of (i) is determined and the contents of storage in the symbol storage section 32 are updated last time with the probable symbol hard decision value at step S7. Next, if it investigates whether the count of decode is a predetermined value at step S8 and has not become a predetermined value, it returns to step S1. It returns to step S1 in drawing 3 through step S12 in drawing 3 correctly.

[0044] If judged with decode processing not being 1 time at step S2, it will read from the symbol storage section 32 last time by step S9, the last storage symbol, i.e., probable hard decision symbol, channel presumption will be performed using this and the information symbol sequence of input-signal r (k), and it will move to step S3. In the above, also in processing of the 2nd henceforth, unique WORD carried out channel presumption from the initial state as a reference sign, and 2nd henceforth may use only the hard decision symbol appropriate for ** as a reference sign. In this case, it investigates whether it is the 1st processing by step S1', and if it is the 1st processing, a channel value is presumed for unique WORD by this and the input signal as a reference sign by step S2', and as a broken line shows in drawing 6 , after memorizing that presumed channel value and the value of each parameter used for that presumption in the storage section by step S3', it will move to the identification of step S3, and decode processing.

[0045] If it is not the 1st time in step S1', in advance of channel presumption processing, the channel estimate and the various processing parameters which were previously memorized by step S4' will be set up, and it will move to step S9. The solution (32) to serves as a degree type in a place.

wn (k) =(HG(k) HH+sigma2 I)-1 and h (34)

I is a unit matrix and sigma2. It is the internal-noise power (covariance of a noise component) of a receiver, and sigma2 I corresponds to the covariance matrix of a noise component, and G (k) corresponds to a channel presumption square error.

[0046]

G (k) **E [(B (k)-B' (k)) -(B (k)-B' (k)) H]

= diag [D (k+Q -1), --, D (k), --, D (k-Q +1)]

(35)

E[] expresses an average and diag expresses a diagonal matrix (elements other than the element of the diagonal line are zero). Again D(k+q) =diag [1-b'21 (k+q), --, 1-b'2 n (k+b), --, 1-b'2 N] (k+q) (36)

At the time of q=Q -1, Q-2, --, -Q+1, and q!=0q=0 D(k) =diag [1-b'21 (k), --, 1, --, 1-b' 2 N (k)]

(37)
One in Vector D (k) is the n-th element (it is considering as the signal of a request of the n-th user's sending signal).
[0047]
[Equation 19]

$$h=\begin{bmatrix} H_{1,(Q-1)\cdot N+n} \\ H_{2,(Q-1)\cdot N+n} \\ \vdots \\ H_{M\cdot Q,(Q-1)\cdot N+n} \end{bmatrix} \quad (38)$$

[0048] That is, h consists of all elements of eye a -(Q-1) N+n train of H of a formula (23). The channel matrix H presumed with the channel presumption vessel 28 in the filter coefficient presumption section 317-1 of the multi-output equalizer 31 as shown in drawing 2 , and noise power sigma2 Soft decision transmitting symbol b'1 from the soft decision symbol generation section 313-1 (k) - b'N (k) is inputted and the residual interference removal filter factor wn (k) calculates by formula (34) - (38). Although an inverse-matrix operation will be performed, as for a formula (34), this operation can reduce the amount of operations by using the lemma (Matrix Inversion Lemma) of an inverse matrix. That is, a formula (36) and b'each 2 of (37) When all parts are approximated to 1, it is D(k+q) =diag[0, —, 0] =0. (q!=0) (39)
D(k) =diag (0, —, [1, —, 0]) (40)
That is, as for all other elements, only the element of the n line n train in the element of D (k) is set to 0 by 1. It is wn if error matrix [of the formula (35) decided by these formulas (39) and (40)] G (k) is substituted for a formula (34). (k) =(h-hH+sigma2 I)-1 and h (41)
It becomes. h was defined by the formula (38).
[0049] By this approximation, it is wn. In order that (k) may not be dependent on k, it becomes unnecessary inverse-matrix calculating [of every discrete time of day k], and computational complexity is reduced. The lemma of an inverse matrix is applied to this formula (41). The lemma of this inverse matrix makes the square matrix of (M, M), and C as a matrix (M, N), and makes D the square matrix of (N, N) for A and B, and it is A=B-1+CD-1 CH. When expressed, it is the inverse matrix of A. (42) A-1=B-BC(D+CH BBC)-1CH B
It is come out and given. It is set to -1+CD-1CHh(k) -h(k) H =CD-1 CH, sigma2 I=B -1, h(k) =CI=D -1, and h(k) H =CH. if this theorem is applied to the part of the inverse-matrix operation in a formula (41) — h(k).-h(k) H+sigma2 I=B — If a formula (42) is calculated using this, the inverse-matrix operation in a formula (41) can be found. In addition, although the inverse-matrix operation (D+CH BBC) -1 is included also in a formula (42), since this inverse matrix serves as Scala, it is easily calculable.
[0050] That is, it is wn in this case. (k) =1/(sigma2+hH and h) h (41-1) It becomes. 1/( ) of the right-hand side of this formula is good also as 1, scalar, i.e., since it becomes in fixed numbers. Therefore, wn Since it can place with (k) =h, it is w only at h. (k) is determined. What is necessary is to input into the filter coefficient presumption section 317-1 in drawing 2 only h shown by the formula under channel matrix H (38) from the channel presumption machine 28, as a broken line shows.
[0051] In addition, the approximation by the formula (39) and the formula (40) can lessen computational complexity of a formula (34) not only when using the lemma of an inverse matrix, but by this approximation. If especially this approximation is performed, and the lemma of an inverse matrix is used, the amount of operations can be decreased further and the covariance matrix of a noise component will be set to sigma2 I in that case, it is wn as shown in a formula (41-1). It can approximate by (k) =h, and becomes unrelated to a covariance matrix, and count is simplified further.
Signal bn detected in the identification processing which subtracts H-B' (k) from receiving vector y (k) shown in the 2nd invention (error correction reflection) type (27) The transmitting symbol soft decision value of signals other than (k) is the signal bn detected although the error correction decode result is reflected. The error correction decode result about (k) is not

reflected. Then, processing as follows is desirable.
[0052] It changes into a degree type, b' (k) (31), i.e., the formula, in a formula (29).
b -- ' -- (-- k --) -- = -- [-- b -- ' -- one -- (-- k --) -- -- b -- ' -- two -- (-- k --) -- -- b'n - one -- (-- k --) -- -- f (b'n (k)) -- -- b'n -- + -- one -- (-- k --) -- b'N -- (k) --] -- (43)
however, f (b'n (k)) -- b'n the function of the arbitration which considers (k) as an input -- signal bn detected by doing in this way It becomes possible to make an error correction decode result reflect also about (k). That is, it is without it is referred to as b'n (k) =0 (the signal which carries out **** leak ****** will be emphasized to a noise or an interference signal, and bn (k) can be correctly detected by adding the suitable value according to b'n (k).).
[0053] About f (b'n (k)), it is b'n. The sign of (k) is b'n. It is related to the hard decision result of the symbol corresponding to (k), and b'n. It is b'n, so that the absolute value of (k) is large. It is necessary to fulfill the following conditions from the property in which the dependability of the hard decision symbol corresponding to (k) is large. b'n When the dependability of (k) =0, i.e., a hard decision symbol, is 0, the value of this function f is also 0. namely, -- f(0) =0 (44)
It comes out. Moreover, b'n If the value of (k) is large, the value of Function f will also turn into a big value. namely, -- d{f(b'n (k))}/d{b'n (k)} >=0 (45)
It comes out. As the example of such f (b'n (k)) f(b'n (k)) = alphaxb'n (k) (46)
f(b'n (k)) = alphaxb'n 2 (47)
************. For example, a constant, then a formula (43) are [alpha] easily realizable using a formula (46). alpha is 0< alpha<0.6 here. If alpha is made larger than 0.6, a BER (error rate) property will deteriorate conversely and a right decode result will no longer be obtained. Moreover, carrying out adjustable [of the alpha] according to the reliability of a decode result is also considered. For example, alpha is set up for every repeat of decode processing. In this case, what is necessary is just to enlarge the value of alpha according to the count of a repeat of decode processing, in order that the reliability of a decode result may go up so that the count of a repeat of decode processing usually increases. Or what is necessary is to judge the reliability of the whole frame decoded for every repetition of decode processing, and just to determine the value of alpha based on the judgment. How to count the number of hard decision symbols which changed for example, the decode result from the time of the last decode as an approach of judging the reliability of the decoded frame, as compared with the decode result at the time of repeat decode 1 time ago can be considered. Namely, what is necessary is to judge with reliability being low, when there are many hard decision symbols which changed, and just to judge with reliability being high, when there are few hard decision symbols which changed.
[0054] Moreover, such b'n It follows on modification of (k) and is the multiplier wn of an MMSE (2nd [an average of] power error of the minimum) filter. It is desirable to change as follows the formula (35) used in case it asks for (k).
G (k) =E[(B(k)-B' (k)) - (B(k)-B' (k))
)H]
= diag [D (k+Q -1), --, D (k), --, D (k-Q +1)]
It is [0055] from a formula (29) and a formula (31) here.
[Equation 20]

$$B'(k)=\begin{bmatrix} b'(k+Q-1) \\ b'(k+Q-2) \\ \vdots \\ b'(k) \\ \vdots \\ b'(k-Q+1) \end{bmatrix} \qquad b'(k)=\begin{bmatrix} b'_1(k) \\ b'_2(k) \\ \vdots \\ -f(b'_n(k)) \\ \vdots \\ b'_N(k) \end{bmatrix}$$

[0056] It carries out. The element of the n line n train of D (k) is E [[(bn (k)+f (b'n (k)))] and [and] (bn (k)+f (b'n (k)))] *[ ]*. A complex conjugate is expressed. In a BPSK modulation, this

formula turns into a degree type.
E — [— bn — (— k —) — two — + — 2b — n — (— k —) — f (b'n (k)) — + — f (b'n (k)) — two —] — = — E — [— bn — two — (— k —) —] — + — two — E — [— bn (k) f (b'n (k)]+E [f (b'n(k)2]))
The average of this 1st term is set to 1. Moreover, bn A formula (37) is as follows when (k) is approximated by b' (k).
[0057]
D (k) — =diag[1-b'21(k) 1- b'22(k) — 1-b'2n- 1 (k) — 1+2E[f (b'n (k) b'n (k))]+E[— f (b'n (k)2] — 1-b'2n+1 (k) — 1-b'21 (k) —])
(48)
For example, D (k) is as follows when f (b'n (k)) is made into a formula (46).
D — (— k —) — = — diag — [— one - b — ' — 21 — (— k —) — — one - b — ' — 22 — (- - k —) — — one - b — ' — two — n - one — (— k —) — — one — + (2 alpha+alpha 2) — b — ' — two — n — — (— k —) — — one - b — ' — two — n — + — one — (— k —) — 1- b'21 (k) —] — (49)
Thus, when making an error correction decode result reflect in the signal to detect, it is the adaptation filter factor wn. It is the sending signal b1 from the 1st transmitter as a signal which detects the example of a functional configuration which presumes (k). The case where it is referred to as (k) is shown in drawing 7 A. Soft decision transmitting symbol b'1 (k) is inputted into the function operation part 331-1, and the function operation f (b'1 (k)) calculates. Moreover, soft decision transmitting symbol b'1 from the decoder of N individual (k) - b'N (k), and f (b'1 (k)) are inputted into the error matrix generation section 332-1, and operation generation of the error matrix G (k) is carried out by a formula (35), a formula (36), and the formula (48). This error matrix G (k), and the presumed channel matrix H and noise power sigma2 It is inputted into the filter factor generation section 333-1, a formula (34) is calculated here, and it is the adaptation filter factor wn. (k) is presumed. In this case, f (b'n (k)) is inputted also into the interference replica vector generation section 314-1, and interference replica vector B[of a formula (30) and a formula (43) to a formula (29)] ' (k) is generated. filter coefficient wn (k) — difference — vector y' (k) carries out filtering in the adaptation filter section 318-1 — having — a logarithm — likelihood ratio lambda 1 [b1 (k)] is obtained. In addition, in the case of the filter factor presumption section 317-1 in drawing 2 , the function operation part 331-1 in drawing 7 A is omitted, and it is the soft decision transmitting symbol b'1. (k) - b'N (k) will be inputted into the error matrix generation section 332-1, and a formula (34) will calculate.
[0058] Although interference replica vector B' (k) is generated by step S4 in drawing 3 , steps S5-S7 are processed further and it asks for the filter factor wn in step S8 (k) When calculating a formula (34) in processing of this step S8 As shown in drawing 7 B, it is the soft decision transmitting symbol b'1 at step S8-2. (k) - b'N (k) is used. Formula (35) - (37) is calculated, error matrix G (k) is generated, and it is error matrix G (k), the presumed channel matrix H, and noise power sigma2 at step S8-3. It uses and is the adaptation filter factor wn by the operation of a formula (34). It asks for (k).
[0059] To reflect an error correction decode result in the signal detected as mentioned above Soft decision transmitting symbol b'n of a signal to detect by step S8-1 before step S4 in drawing 7 B The function operation of the (k) is carried out. What is necessary is to use a formula (43) instead of a formula (31), that is, for a formula (29), a formula (30), and a formula (43) to generate interference replica vector B' (k), and just to use a formula (48) instead of a formula (37) by step S4, step S8-2 using this. As mentioned above, it is f (by the case where it considers as alphab'n (k) or alphab'n (k) 2, b'n (k)). When changing alpha, the reliability of the count of processing or the decoded whole frame determines alpha by step S8-1-1, and it is 1+(2 alpha+alpha 2) b'n at step S8-1-2. 2 What is necessary is to calculate and just to use as f (b'n (k)).
[0060] The technique of making an error correction result reflect in this signal to detect is applicable also to the single user turbo receiver explained by the term of the conventional technique. Moreover, what is necessary is to be able to apply the approximation shown in a formula (39) and (40), and just to input into the filter coefficient generation section 333-1 the

matrix h shown in a formula (38) from the channel presumption machine 28 in this case, in the technique of making an error correction result reflect in this signal to detect, as a broken line shows in drawing 7 A. By ****, it is the adaptation filter coefficient wn. Although it asked for (k) by the formula (34), that is, being asked using the channel matrix H, it is not necessary to use the channel matrix H. That is, in the 1st time of decode processing (turbo reception), the error vector G in a formula (34) serves as a unit matrix. therefore, difference — vector y' (k), a training signal or this, and hard decision transmitting symbol b^n (k) — it mentioned above preferably — as — b^n with high reliability (k) — the filter factor generation section 333-1 — inputting — RLS (recursive least square method) etc. — applying — serially — a target — adaptation filter factor wn (k) may be computed. The error vector G is the adaptation filter coefficient wn 2nd after repeat processing of decode, in order to be dependent on the discrete time of day k. It is necessary to update (k) for every symbol, as stated previously, the channel matrix H is used, and it is the adaptation filter factor wn. It is desirable to determine (k).

[0061] The 4th invention (channel presumption)

It repeats, as mentioned above. To channel presumption the hard decision value of not only known information like unique WORD but an information symbol, and also using especially the probable thing as a reference sign Not only in when using for said multi-input multi-output turbo receiving approach, generally Presume the channel (transmission line) of an input signal from an input signal and a known signal, decode by processing an input signal using the presumed channel value, and the decode signal is used. It is applicable to the turbo receiving approach of performing the processing and decode processing by the channel value which repeated and presumed the same input signal.

[0062] The example which also applied the hard decision value of this information symbol to channel presumption and the turbo equalizer 41 at drawing 8 is shown. The turbo equalizer 41 determines a linear equalization filter factor with a presumed channel value, processes an input signal with the linear equalization filter, decodes the processed signal, and repeats and processes the same input signal using the decode signal. Input-signal r (k) is supplied to the channel presumption machine 42 while it is inputted into the turbo equalizer 41. With the channel presumption vessel 42, a channel value (line characteristic) is presumed by input-signal r (k) and the unique WORD from the storage section 29. Identification processing of the input-signal r (k) is carried out by the presumed channel value within the turbo equalizer 41, and after that, while decode processing is carried out and decode data c' (i) is outputted, soft decision value b' (i) is outputted. By being inputted into the symbol selection machine 43, if the absolute value of soft decision value b' (i) is more than threshold Th, soft decision value b' (i) Updating storing of the hard decision value b^ (i) is carried out last time as a probable (reliable) thing at the symbol storage section 32. In the channel presumption processing in the channel presumption section 42 at the time of repeating and carrying out reception (equalizing processing) of the future same input-signal r (k), not only unique WORD but hard decision value b[of the information symbol memorized by the symbol storage section 32 last time]^ (i) is used.

[0063] The turbo equalizer 41 is a part except the symbol storage section 32 the repeat channel presumption machine 28 receiving in a plane shown in drawing 1 , the unique WORD storage section 29, and last time. You may be a receiver in drawing 29 . That is, the solution (19) to serves as the following by the Wiener solution also in this case.

w(k) =E[y'(k) y'H (k)] and E[b (k) -y' (k)

]

= [Hlambda(k) H+sigma 2 I] -h (50)

It is the thing and sigma2 =E [||v||2] (distribution of a noise) as which H was defined by the formula (8) here, and h**[H (Q-1), —, H (0)] TH( ) was defined by the formula (5).

lambda(k) =diag[— 1-b' — 12 (k+Q -1), —, 1, —,-b'2] (k-Q +1)

Thus, also in the receiver in drawing 29 , presume channel H ( ), it identification filter-factor w (k) Asks using this channel H ( ), filtering of the input signal is carried out by filter factor w (k), and decode processing is performed to that processed output. Therefore, in this repeat reception, right channel presumption can be obtained more by using a hard decision information symbol with said dependability for channel presumption.

[0064] Drawing 9 shows the example of the turbo receiver which applied said repeat channel presumption approach to the repeat reception which performs lake (RAKE) composition processing. Input-signal r (k) is supplied to the RAKE composition processing section 45 and the channel presumption machine 42. A channel value is presumed by input-signal r (k) and unique WORD with the channel presumption vessel 42, and compensation over the phase rotation which each symbol received in the RAKE composition processing section 45 in the transmission line, and RAKE composition processing are performed by the presumed channel value, that is, time diversity processing is performed, and the 1st time is outputted to the turbo decoder 46. Decode data c' (i) and soft decision value b' (i) are outputted from the turbo decoder 46. Soft decision value b' (i) is inputted into the symbol selection machine 43, and like said example, although seemingly it is the **, updating storing of hard decision value b[of an information symbol]^ (i) is carried out last time at the symbol storage section 32. In the repeat reception of RAKE receiving-turbo decoding of the 2nd henceforth, not only unique WORD but the hard decision value of the last information symbol is used for channel presumption with the channel presumption vessel 42. Thereby, since presumption of a channel can carry out to accuracy more, improvement in quality can be aimed at.

[0065] Drawing 10 shows the example of the turbo receiver which used the adaptive (adaptation) array antenna and which applied said repeat channel presumption approach to reception repeatedly. Input-signal r (k) is received by the adaptive array antenna receive section 47. The branching input of the input signal is carried out at the channel presumption machine 42, and channel presumption is performed by this and unique WORD. Using the presumed channel value, toward the arrival direction of the purpose wave, the main beam of the antenna directional characteristics of the adaptive array antenna receive section 47 so that null may be suitable in the arrival direction of an interference wave The weight to each antenna element or a corresponding receiving path is determined in the array weight decision section 48, and the weight is set as an applicable part. The reception output of the adaptive array antenna receive section 47 is supplied to the turbo decoder 46, and is decoded, the decode data c' (i) and soft decision value b' (i) are outputted, soft decision value b' (i) is inputted into the symbol selection machine 43, and the updating storage of the probable hard decision value is carried out last time at the symbol storage section 32. In the repeat reception of the adaptive array antenna receive section 47-turbo decoder 46 of the 2nd henceforth, not only unique WORD but the hard decision value of the last information symbol is used for channel presumption with the channel presumption vessel 42. Channel presumption is performed more correctly by this, consequently control of antenna directional characteristics is performed more to accuracy, and improvement in quality can be aimed at.

[0066] In addition, if the turbo equalizer 41 in drawing 8 is shown simple, as shown in drawing 11 A, it will be the format of the series connection of ************ (SISO) equalizer (equalizer) 41a and SISO decoder (decoder) 41b, and repeat actuation will be performed between these equalizer 41a and decoder 41b. If the turbo decoder 46 in drawing 9 and drawing 10 is shown simple, as shown in drawing 11 B, it will be the format of the series connection of SISO decoder 46a and SISO decoder 46b, and decode will be repeatedly performed between decoder 46a and 46b. Even for a SISO decoder, drawing 9 R> 9 and the turbo decoder 46 in drawing 10 are.

[0067] The example shown in the above drawing 8 thru/or drawing 10 is collectively shown in drawing 12 . That is, it processes with the channel value which repeated the input signal and was first presumed with the channel presumption vessel 42 with the receiver (turbo receiver) 49. Carry out decode processing of the processed signal, output decode data (symbol) c' (i) and its soft decision value b' (i) as the decode processing result, and the soft decision value b' (i) is set in the symbol selection vessel 43. As compared with a threshold, that judged whether correspondence decode data c' (i) and a (symbol hard decision value) would be probable, and judged that is probable carries out updating storing of the hard decision value last time at the symbol storage section 32. It is made to perform channel presumption besides known information like unique WORD at accuracy to channel presumption in the channel presumption machine 42 in the repeat of processing-decode processing using the presumed channel value of the 2nd henceforth more also using the last symbol hard decision value.

[0068] The example of the procedure of the repeat input-signal approach of also using this symbol hard decision value for drawing 13 is shown. A channel value will be presumed with an input signal and a known signal at step S1, and it will investigate whether it is the 1st time of repeat processing at step S2, and if it is the 1st time, an input signal is processed with the channel value presumed at step S1 by step S3, after that, decode processing will be performed and a symbol hard decision value and a soft decision value will be calculated. The last symbol hard decision which memorizes to drawing by step S4 and has memorized what has the symbol soft decision value to a probable correspondence symbol hard decision value in the storage section 32 at step S5 at the taken-out symbol hard decision value is updated. Decode processing investigates whether it is a count of predetermined at step S6, and if it is not a count of predetermined, it returns to step S1. If it is not the 1st time of repeat processing at step S2, the last symbol hard decision value will be read from the storage section 32 at step S7, this and the information symbol of an input signal will perform channel presumption, and it will move to step S3.
[0069] As step S1' - S4' explained with reference to drawing 6 also in this case, processing of the 2nd henceforth does not need to use a known signal. Between the adaptive array antenna receive section 47 and the turbo decoder 46, as a broken line shows the example shown in drawing 10 , the RAKE composition processing section 45 may be inserted. In this case, channel presumption for each symbol phase spin compensation in the RAKE composition processing section 45 and RAKE composition may be made to serve a double purpose with the channel presumption vessel 42, and may be prepared according to an individual.
[0070] It processed in the example of the 2nd invention in consideration of the example and error correction of the turbo receiving approach (the 1st invention) which carried out the noise above-mentioned other than the white nature Gaussian random noise, and the example of the turbo receiving approach (the 4th invention) of having the description in the channel presumption approach, having assumed that a noise was white nature Gaussian random noise. Namely, input signal rm of each antenna vm in the right-hand side of the formula (20) showing (k) (k) is assumed in case of white nature Gaussian noise. White nature Gaussian noise follows Gaussian distribution, and is E[vm (k) and vm] (k-q) =sigma2 here. : In the case of q= 0, in the case of 0:q! =0, E[] is expected value and sigma2. It is a variance. It is the signal which has the becoming statistical property. The thermal noise which generates white nature Gaussian noise within an antenna element is mentioned as an example. It is a filter factor wn that the assumption of this white nature Gaussian noise is reflected. It is the part of sigma2 I in the formula (50) which asks for the formula (34) which asks for (k), or filter factor w (k). For example, wn of a formula (34) (k) and wn (k) =(HG(k) HH+E [n(k) and nH (k)])-1h = (HG(k) HH+sigma2 I) it is computed through a -1h process. Here, it is vm. (k) is distributed sigma2. It is calculated with n(k) and E[nH (k)] =sigma2 I by assumption called the white nature Gaussian noise which it has. channel matrices H and sigma2 presumed by the repeat channel presumption machine 28 (drawing 1) or 42 (drawing 1212) beforehand — a logarithm — error matrix G (k) calculated from a likelihood value — a formula (34) — substituting — filter factor wn (k) is computed.
[0071] In a place, it is Noise vm. The case where (k) is not white nature Gaussian noise is considered. In this case, since it cannot be referred to as n(k) and E[nH (k)] =sigma2 I, it is a filter factor wn. In order to compute (k), it is necessary to presume expected-value (covariance) matrix [of a noise component] E [n(k) and nH (k)] by the option. This approach is explained below. The covariance matrix of a noise component is written as U**E [n(k) and nH (k)] here. It will become a degree type, if y(k) =H-B(k)+n (k) of a formula (22) is transformed with n(k) =y(k)-H-B (k) and it substitutes for a covariance matrix U.
[0072]
U=E [n(k) and nH (k)]
= E [(y(k)-H-B (k)) -(y(k)-H-B (k)) H]
Now, if B (k) is [input signal] available by estimate H^ of the channel matrix H, and the reference sign in vector y (k) and channel estimate, Matrix U is a time average method.
U^=sigmak=0 Tr (y(k)-H^-B (k)) and (y(k)-H^-B (k)) H (51) It can presume. Here, Tr is the number of reference-sign symbols.

[0073] Covariance-matrix U^ is presumed with the channel matrix H using a formula (51) during the repeat channel presumption machine 28 or repeat channel presumption in 42. The procedure is shown in drawing 14 . The unique WORD and the information symbol sequence in one frame in an input signal are shown in drawing 14 A, and processing of the 1st henceforth is shown in drawing 14 B. The 1st processing makes only unique WORD a reference sign, and presumes the channel matrix H first. Next, U is presumed to be unique WORD by the formula (51) using the channel matrix estimate H^. These estimate U and H^ are used and it is a filter factor wn (k).
wn (k)=(H^G(k)H^H +U^)-1h (52)
It computes and is this filter coefficient wn. 1st identification to an input signal is performed using (k), and a transmit information symbol is presumed.
[0074] Among the information symbols presumed to be unique WORD by the 1st identification, the 2nd processing re-presumes U, after re-presuming H in the same procedure as the 1st time by making into a reference sign both thing * judged that is probable with the threshold. By repeating this actuation, for every repeat, channel matrix estimate H^ becomes more exact, and the estimate of U becomes more exact, and it is a filter factor wn. The precision of (k) goes up and the property of an equalizer improves. Turbo reception in case the noise which is not white nature Gaussian random noise is included in an input signal by the above processing can be performed.
[0075] as the identification output of the input signal of the sending signal from the 1st transmitter of the multi-output equalizer 31 which showed the functional configuration in the case of presuming the covariance matrix U of the noise in the input signal mentioned above, and performing linear equalization processing in drawing 2 — a logarithm — likelihood ratio lambda 1 The example applied when asking for [b1 (k)] is shown in drawing 15 . The same reference number is attached to drawing 2 in drawing 15 , and a corresponding part. Last time, the unique WORD from the unique WORD storage section 29 or the last symbol hard decision probable from the symbol storage section 32 is inputted into the reference vector generation section 319, and reference vector B (k) is generated by a formula (25) and the formula (26) here. This reference vector B (k), presumed channel matrix H^ from the channel presumption machine 28, and receiving vector [from the receiving vector generation section 311] y (k) are supplied to the covariance-matrix presumption section 321, a formula (51) is calculated here, and presumed matrix U^ of a covariance matrix U is obtained.
[0076] Moreover, the soft decision transmitting symbol soft decision b'1 from the soft decision symbol generation section 313-1 (k) - b'n Error matrix G1 to which (k) is inputted into the error vector generation section 322-1, and corresponds with a channel presumption square error by the formula (35), the formula (36), and the formula (37) here (k) is generated. This error matrix G1 (k), presumed covariance-matrix U^, and presumed channel matrix H^ are supplied to the filter presumption section 323-1, a formula (52) is calculated here, and it is a filter factor w1. (k) is presumed. this filter coefficient w1 the difference from (k) and the difference operation part 316-1 — filtering [as opposed to / vector y' (k) is supplied to the adaptation filter 318-1, and / y' (k)] w1 (k) H y' (k) should do — that result — a logarithm — likelihood ratio lambda 1 It is outputted as [b1 (k)].
[0077] When making an error correction decode result reflect also about the signal to detect As a broken line shows in drawing 15 , form the function operation part 331-1 shown in drawing 7 R>7A, and f (b'n (k)) is calculated. What is necessary is to use a formula (43) instead of a formula (31) in the interference replica vector generation section 314-1, and just to use a formula (48) instead of a formula (37) in the error vector generation section 322-1. The technique shown in drawing 14 B is shown in drawing 16 as a flow chart. That is, the channel matrix H will be presumed using input-signal r (k) and a known signal (for example, unique WORD) at step S1, and next, it investigates whether this processing is the 1st time in repeat processing at step S2, and if it is the 1st time, it will calculate a formula (51) using a known signal, presumed channel matrix H^, and input-signal r (k) at step S3, and will ask for presumed covariance-matrix U^.
[0078] A formula (52) is calculated using error matrix G (k) which becomes presumed channel matrix H^ and presumed covariance-matrix U^ with a symbol soft decision value by step S4, and it is a filter factor wn. (k) is presumed. step S5 — presumed channel matrix H^ and filter factor

wn (k) — using — an input signal — identification processing — carrying out — that is, a formula (27) — calculating — wn H (k) -y' (k) — calculating — a logarithm — likelihood ratio lambda 1 It asks for [bn (k)], decode processing is performed to this, and the hard decision value and soft decision value of a transmitting symbol are presumed.

[0079] Step S6 calculates the probable (it is reliable) symbol hard decision value which corresponds from the symbol soft decision value more than a threshold. With this symbol hard decision value, the symbol hard decision value stored in the symbol storage section 32 last time is updated. Then, if it has not come to investigate whether the count of decode processing became a predetermined value at step S8 and is return and a predetermined value to step S1, the processing to the receiving frame will be ended. If the processing in repeat processing is not the 1st time at step S2 (i.e., if it is 2nd henceforth), a symbol hard decision value will be read from the symbol storage section 32 last time by step S9, the channel matrix H will be presumed by this and the information symbol in an input signal, and it will move to step S3.

[0080] 2nd henceforth can be prevented from using a known signal by changing steps S1 and S2 into the same processing as step S1' shown with the broken line in drawing 6 also in this case - S4'. Moreover, what is necessary is to perform the function operation f (b'n (k)) at step S10 into drawing 16 , as a broken line shows when the signal to detect also wants to make an error correction decode result reflected, and just to ask for error matrix G (k) using this result. Furthermore, in the case of which, it is not necessary to use a hard decision transmitting symbol at presumption of covariance-matrix U^. it is said below that the covariance matrix U of that noise in the input signal in which the noise which is not this white nature Gaussian noise was included can be presumed — as — various kinds — it is applicable to useful application.

[0081] (1) The receiving method for the multi-sequence sending signal in which an interference signal with a strange receiver is included is mentioned. As shown in drawing 28 , suppose that strange interference signal i (k) (for example, signal from the cel and zone of others [mobile communication]) is received by the turbo receiver in addition to the sending signal of the sequence of N individual like the signal from the transmitter of the user of N man whom a turbo receiver tends to receive as a broken line shows. At this time, it is a formula (20). rm (k) =sigmaq=0 Q-1 sigman=1 N hmn(q) and bn+(k-q +1) i(k)+vm (k) It becomes (20) '. It sets to this model and is i(k)+vm. (k) **v'm If (k) rm (k) =sigmaq=0 Q-1 sigman=1 N hmn(q) and bn+(k-q +1) v'm (k) It becomes (20) ". v'm As a noise signal which is not white nature Gaussian noise, (k) performs presumption of H, and presumption of further U, as stated previously, and it is wn. (k) can be presumed and turbo reception can be performed by repeating identification processing of an input signal, and transmitting symbol presumption.

[0082] (2) In the communication system using a transceiver separation filter, in case over sampling technique is performed from 1/2 of a symbol period to an input signal at high speed, correlation cannot come out between the noise components contained in the input signal by which the sample was carried out by each time amount, and it cannot be considered that the noise in an input signal is white nature Gaussian noise. That is, it sets at a ceremony (20) and is E[vm (k) and vm] (k-q) =sigma2. : In the case of q= 0, it does not become the case of 0:q!=0. Therefore, the assumption E[n(k) and nH (k)] =sigma2 I Becoming cannot be performed. Then, by performing processing to the input signal separated with the transceiver separation filter in quest of a covariance matrix U using a formula (51), an input signal can be processed correctly.

[0083] (3) By the turbo receiving approach mentioned above, all the multi-pass components of Q pass from each transmitter (user) are compounded, and it has become constructing. however, when a long delay wave exists in a channel (example: — pass — the pass component of 1 symbol delay, 2 symbol delay, and 30 symbol delay in case it is 3-symbols-delayed, and it flies and 30 symbol delay exists), it is possible to take the plan which does not compound a long delay wave, but treats it as strange interference, and is removed with an adaptation filter. That is, a long delay wave is removable by treating this long delay wave component as interference signal i (k) in the example of the above (1).

[0084] In the processing to the input signal in which the noise which is not the white nature Gaussian noise mentioned above was included Presumption of a covariance matrix U is presumed instead of sigma2 I in a formula (50). Are applicable also to the single user turbo

receiving approach. Similarly A single user, Irrespective of multiuser, it is applicable to the turbo reception using the adaptive array antenna reception shown in the RAKE composition processing reception shown in drawing 9 , or drawing 10 , channel presumption with the channel [in / repeatedly / decode] presumption vessel 42 still more generally shown in drawing 12 , and presumption with a covariance matrix U. In addition, in RAKE reception, only channel presumption may be used.

[0085] the 3rd invention (multistage identification) **** -- input signals r1, --, rM the multi-output equalizer 31 -- it is -- equalizing -- a logarithm -- likelihood ratio lambda 1 [b (k)], --, lambdaN Although it asked for [b (k)], in the modification (2) of the 1st invention, two or more identification stages are prepared in concatenation, and a more nearly latter equalizer is good also as a configuration which lessens the number of outputs. For example, as shown in drawing 17 , by dividing into two for this, with the preceding paragraph equalizer (multiuser equalizer) 71, the interferent component outside the identification range of latter single user equalizer 21' is canceled, therefore pretreatment of software interference cancellation and MMSE (2nd [an average of] power error of the minimum) norm linearity filtering is performed, for example, and the numbers of passes shown previously perform identification processing of the single user of Q by latter-part equalizer 21' after that.

[0086] Thus, identification processing is carried out in concatenation and computational complexity can be prevented from becoming immense also by using a linearity filter for processing of the preceding paragraph. The example of the MIMO structure of a system to which the configuration and this invention of the example based on the underlying concept of the 1st invention (2) of this turbo receiving method of a multi-output turbo receiver are applied is shown in drawing 18 , the same reference number is attached to drawing 1 and a corresponding part, and duplication explanation is omitted (the same is said of the following explanation). The sending signal from each transmitter is received through a transmission line (channel) by the turbo receiver 30. This input-signal r (k) is inputted into the multiuser equalizer 71. From this equalizer 71 Signal u1 with which interference by the signal from the transmitter of others [signal / from each transmitter of N individual] was removed, respectively (k), -- and uN (k) and each channel value alpha 1 (k), --, alphaN (k) is outputted and it is inputted into the single user equalizer 21-1, --, 21-N, respectively. from these SISO(s) equalizer 21-1, --, 21-N -- respectively -- a logarithm -- likelihood ratio lambda 1 [b1 (k)], --, lambda 1 [bN (k)] is outputted. Although future processings are the same as that of the case of drawing 1 R> 1 than this, they are the single user equalizer 21-1, --, the channel value alpha 1 used by 21-N. (k), --, alphaN (k) is a channel value after multiuser identification, and differs from the channel matrix H. Therefore, this alpha 1 (k), --, alphaN (k) is described as the channel information after identification.

[0087] Hereafter, actuation of each part is explained. In consideration of several Q of a multi-pass (channel), formula (23) - (26) is defined like explanation of drawing 1 . An equalizer [of the latter part in drawing 18] 21-1, --, according [21-N] to signal symbol (bn (k), and [bn (k-1), --, bn] (K-Q +1) (n= 1, --, N)) of each user's self intersymbol-interference channel is equalized. Therefore, in the equalizer 71 of the preceding paragraph, processing which removes interference other than the above (bn (k), and [bn (k-1), --, bn] (K-Q +1) (n= 1, --, N)) in y (k) is performed. The quantitive explanation is given to below.

[0088] First, a decoder 24-1, --, prior information lambda2 p of the equalizer 71 fed back from 24-N It asks for soft decision transmitting symbol presumption b' (k) by the formula (15) using [bn (k)] (n= 1, --, N). Next, these soft decision transmitting symbol b'n Replica H-B[of an interference signal] ' (k) is created using (k) and the channel matrix H, and it subtracts from receiving vector y (k).

y'n(k) **y(k)-H-B' (k) (27) ' B'(k) =[b'T --(k+Q -1) b'T (k) --b'T] (k-Q +1) T H-(B(k)-B' (k)) +n (k) and (28) ' -- = here (29) -- ' -- and b'(k+q) =[b'1 b(k+q) '2 (k+q) -- b'n --(k+q) b'N (k+q)]T : q=Q- 1, --, 1 (53) b'(k+q) =[b'1 b(k+q) '2 --(k+q) 0 --b'N] (k+q) T : q= 0 and -- -Q+1 (54)

(The zero in the element of b' (k+q) are the n-th)

Actuation of subtracting this interference below will be called software interference cancellation. y'n (k) which will be obtained after subtraction supposing the replica of an interference signal is made ideally is the n-th user's symbol bn. (k), A formula (54) shows q= 1, --, that it cannot have

in having set the n-th element of b' (k+q) to 0 by -Q+1 only with the intersymbol-interference component by a user's n-th own symbol [bn (k-1), --, bn] (k-Q +1) of ********.

[0089] Although the contribution component from the signal of the n-th user (transmitter) within the receiving vector r (k) is based on a symbol (bn (k), and [bn (k-1), --, bn] (k-Q +1)), it actually sees. But So that I may be understood from the definition of receiving vector [of a formula (21)] y (k) In the contribution component from the signal of the n-th user (transmitter) in receiving BEKURUTOy (k) which compounds by the multi-pass and is made, it is the k-th symbol bn. This is received if based on (k). Symbol [bn (k+Q -1) of the future, bn (k+Q -2), --, the intersymbol-interference component by bn (k+1)] will also be included. That is, the above-mentioned interference replica has also included the interferent component from the future. thus, the difference of formula (27) ' -- vector y' (k) -- the difference of a formula (27) -- it differs from vector y' (k).

[0090] Then, the next step of the preceding paragraph processing in an equalizer 71 is the interference surplus component after software interference cancellation, i.e., the residual interferent component based on said imperfect composition of interference replica H-B' (k), and said future intersymbol-interference component y'n The linearity filter of an MMSE (2nd [an average of] power error of the minimum) norm removes from (k). That is, filter shape wn y'n It is made for the result of having carried out filtering of the (k) as shown in a formula (55) to become equal to channel value alpha1n, alpha2n, --, the sum that carried out the multiplication of the alphaQn, respectively as the symbol in the signal of the n-th user in an input signal (bn (k), and [bn (k-1), --, bn] (K-Q +1)).

wn H (k) and y'n (k) **sigmaq=0 Q-1 alphaq (k) and bn =(k-q) alphan H (k) and bn (k) (55)

Therefore, this filter shape wn (k) and channel value (channel information) alphan after identification What is necessary is just to calculate a formula (55) in quest of (k). It is wn below. (k) and alphan The calculation approach of (k) is shown. In addition, filter shape wn (k) is the filter factor wn given by the formula (32) and the formula (34). Although it differs from (k), the same notation is used for convenience.

[0091] The above-mentioned solution is defined as a solution of the following optimal problems.

(wn (k) alphan (k)) =arg min ||wn H (k) and y'n (k)

- alphan H (k) and bn (k) ||2 (56)

It is contingent [on alpha1n(k) =1]. That is, wn from which the right-hand side of a formula (56) serves as min (k) and alphan It asks for (k). Constraint alpha1n(k) =1 added is alphan. (k) =0 and wn It is for avoiding the becoming solution (k) =0. This is ||alphan. Although solving by the constraint which becomes (k) ||2 =1 is also possible, below, it is alpha1n. The solution in (k) =1 is shown. Since it is easy, a problem is replaced as follows. That is, mn which makes the right-hand side of a formula (56) min about w and alpha It is defined as (k).

[0092]

mn (k) =arg min ||mn H (k) and zn (k) ||2 (57)

mn H It is contingent [on (k) and eMQ+1=-1]. (alpha1n(k) =1 and equivalence)

here -- mn (k) **[wn T (k), -n[alpha] (k) T] T (58)

zn (k) **[yn T (k) b(k) n T] T (59)

eMQ+1= [0--1--0] T (60)

(-- the element of one in eMQ+1 is MQ+1st). The solution of this optimization problem is given below from reference [2] S.Haykin, Adaptive Filter Theory, and the Lagrange method of undetermined coefficients shown in Prentice Hall P.220-P227.

[0093]

mn (k) =-RZZ-1 and eMQ+1/(eMQ+1H, RZZ-1, and eMQ+1) (61)

It is here. RZZ=epsilon [zn (k) and zn H (k)] (62)

epsilon [A] expresses the expected value (average) of A.

[0094]

[Equation 21]

$$= E\begin{bmatrix} H\cdot\Lambda_n(k)\cdot H^H + \sigma^2 I & H_n^H \\ H_n & I \end{bmatrix} \qquad (63)$$

[0095]
lambdan (k) =diag [Dn (k+Q −1), —, Dn (k), —, Dn] (k−Q +1) (64) I is a unit matrix. sigma2 Noise power (variance of white nature Gaussian noise)
[0096]
[Equation 22]

$$H_n = \begin{bmatrix} h_n(Q-1) & 0 & 0 & 0 \\ h_n(Q-2) & h_n(Q-1) & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots \\ h_n(0) & h_n(1) & \cdots & h_n(Q-1) \end{bmatrix} \quad (65)$$

[0097]
Dn =(k+q) diag [1−b'1 2 (k+q), —, 1−b'n 2 (k+q), —, 1−b'N 2] (k+q) : q=Q +1 and — one (66) Dn =(k+q) diag[— 1−b'1 — 2 (k+q), —, 1, —, 1−b'N 2] (k+q) : q= 0, —, −Q+1 (67)
diag expresses a diagonal matrix (elements other than the element of the diagonal line of a matrix are zero). That is, it is mn if the channel matrices H and sigma2 are known. It can ask for (k) by the formula (61). Therefore, a formula (58) is followed and it is wn. (k) and alphan (k) is called for.
[0098] This computed filter shape wn By (k), it is y'n. Filtering of the (k) is carried out by the degree type.
un (k) =wn H (k) and y'n (k) (68)
H expresses a conjugate transposed matrix. This n processing result by which filtering was carried out is sent to equalizer 21−n to which consecutiveness corresponds. Thus, the left part of the formula (1) from the n−th user and the corresponding input signal un (k) is obtained, the channel value hmn (q) of the right−hand side of a formula (1) and corresponding alphamn (k) are obtained, that is, a formula (1) and a corresponding formula (55) can be found. Therefore, alphan (k) is given to consecutive equalizer 21−n as an equalizer parameter (channel value). The above is preceding paragraph processing by the equalizer 71.
[0099] Next, the processing after consecutive equalizer 21−n is described. As mentioned above, since it corresponds with the formula (1), since it is shown in reference [1], a formula (55) omits actuation within equalizer 21−n for every user for details, as stated also above that what is necessary is just to carry out like actuation of the equalizer 21 in drawing 31 . un which defined each equalizer 21−n by the top (k) and alphan the logarithm of the probability for the prior information lambda 2 from (k) and decoder 24−n [bn (k)] to be inputted, and for each coding bit to be +1 as an output, and the probability which is −1 — a likelihood ratio lambda 1 (LLR:Log−Likelihood Ratio) is computed by the degree type.
[0100]
[Equation 23]

$$\Lambda_1[b(k)] = \log \frac{\Pr[b_n(k)=+1 \mid u_n(k), k=0,\cdots,B]}{\Pr[b_n(k)=-1 \mid u_n(k), k=0,\cdots,B]} \quad (69)$$

$$\equiv \lambda_1[b_n(k)] + \lambda_2^p[b_n(k)] \quad (70)$$

[0101] It is lambda 1 here. [bn (k)] is the external information and lambda2p which are sent to consecutive decoder 24−n. [bn (k)] is prior information given to an equalizer 31. decoder 24−n — a logarithm — likelihood ratio lambda 2 It computes by the degree type.
[0102]
[Equation 24]

$$\Lambda_2[b_n(i)] = \log \frac{\Pr[b_n(i)=+1 \mid \lambda_1[b_n(i)], i=0,\cdots,B]}{\Pr[b_n(i)=-1 \mid \lambda_1[b_n(i)], i=0,\cdots,B]} \qquad (71)$$

$$\equiv \lambda_2[b_n(i)] + \lambda_1^p[b_n(i)] \qquad (72)$$

[0103] It is lambda 2 here. [bn (i)] is the external information and lambda1 p which are given to an equalizer 71 and an equalizer 21 in the case of a repeat. [bn (k)] is the prior information given to decoder 24-n. The configuration shown in this drawing 18 performs identification and decode repeatedly, and improvement in an error rate is attained. The functional configuration of the multiuser equalizer 71 mentioned above is briefly explained with reference to drawing 19 . each -- an antenna -- an input signal -- a receive section -- 70 -- a vector -- r -- (-- k --) -- = -- [-- r -- one -- (-- k --) -- rM -- (-- k --) --] -- ****** -- processing -- having -- this -- a vector -- r -- (-- k --) -- using -- reception -- a vector -- generation -- the section -- 311 -- setting -- each -- a multi-pass (channel) -- having taken into consideration -- a formula -- (-- 21 --) -- reception -- a vector -- y -- (-- k --) -- generating -- having .
[0104] On the other hand, input-signal [from a receive section 70] r (k), and each transmitter from the unique WORD storage section 29 and the corresponding known sequence signals, such as a unique WORD sequence for channel presumption, are inputted into the channel presumption machine 28, and the channel matrix H is presumed. moreover, the output of each decoder 24-1, --, 24-N -- a logarithm -- likelihood ratio lambda2 [b1 () [bN (k)] is inputted into the soft decision symbol presumption section 313-1, --, 313-N. i) --], --, lambda2 (k)], --, lambda 2 -- [bN from (i)] -- respectively -- prior information lambda1 p [-- b1 (i)], --, lambda1p [bN External information lambda 2 from which (i)] was deducted [-- b1 It is the soft decision transmitting symbol b'1 by the formula (15), respectively. (k), --, b'N (k) is calculated. These are inputted into the interference vector generation section 72, and vector B[of the symbol estimate which can serve as an interference signal from other transmitters for every n] ' (k) is generated by formula (29) ', (53), and (54) in the interference vector generation section 72. The product of vector B' (k) and the channel matrix H of these N individual calculates, respectively by the other interference signal estimation section 73-1, --, 73-N, and replica H-B (k) of an interferent component is calculated.
[0105] interferent component replica H-B (k) of these N individual subtracts from receiving vector y (k) by the subtraction section 74-1, --, 74-N, respectively -- having -- difference -- a vector y'1 (k), --, y'N (k) is called for. Soft decision transmitting symbol b'1 (k), --, b'N (k) is inputted into the error matrix generation section 75. It is the error matrix lambda 1 by the formula (64), (66), and (67). (k), --, lambdaN (k) is generated. These, the channel matrix H, and noise power sigma2 It is inputted into the filter shape presumption section 76, and is a filter shape wn at the filter shape presumption section 76 by a formula (58), (60), (61), (63), and (65). Channel information alphan after identification It is presumed. these filter shapes w1, -- and wN difference -- vector y'1 (k) -- -- and y'N The multiplication of the (k) is carried out by the filtering section 77-1, --, 77-N, respectively. Filtering is carried out. That is, symbol [bn (k) from each pass for every user, u1 which is bn (k-1), --, the component of which interference [signal / other user] was removed from the input signal of bn (K-Q +1)] (k), -- and uN Channel information alpha 1 after the identification which (k) was obtained, respectively and was asked for it in these and the filter shape presumption section 76 (k), --, alphaN (k) is supplied to the single user equalizer 21-1 in drawing 18 , --, 21-N, respectively.
[0106] The procedure of the 1st invention (2) of this turbo receiving method is shown in drawing 20 . The same step notation was attached to the procedure shown in drawing 3 , and a corresponding step in drawing 20 . However, interference replica vector B'n in step S4 Formula (29) ', (53), and (54) perform count of (k). Step S13 is soft decision transmitting symbol b'n. (k) is used and it is error matrix lambdan by the formula (64), (66), and (67). (k) is generated. Step S14 is a channel, Matrix H, and noise power sigma2. Error matrix lambdan (k) is used and it is the residual interference removal filter wn by a formula (58), (60), (61), (63), and (65). (k) and channel

information alphan It asks. step S15 — difference — vector y'n (k) — residual interference removal filter shape wn (k) — filtering — carrying out — un It asks for (k). step S16 — each filtering result un (k) — receiving — single user identification processing — carrying out — a logarithm — likelihood ratio lambdan It asks for [bn (k)], respectively and decode processing of these is carried out at step S10. Others are the same as that of the processing shown in drawing 3 .

[0107] Although the identification range in latter-part equalizer 21-n is made into the intersymbol-interference section by the symbol (bN (k), and [bn (k-1), —, bn] (K-Q +1) (n= 1, —, N)) in ****, this identification range can be adjusted. For example, as for the case of a very big value, the count load of latter equalizer 21-n becomes [Q] large. In such a case, what is necessary is to set the identification range of latter-part equalizer 21-n to Q'<Q, and just to change so that the equalizer 71 of the preceding paragraph may remove the intersymbol interference of the signal of the same users other than bn (k), and [bn (k-1), —, bn] (K-Q'+1) (Q'<Q, n= 1, —, N) section. This modification is explained later. As it divides into this preceding paragraph identification and latter-part identification and a broken line also shows a **** case in drawing 19 R> 9, in the channel presumption machine 28, the symbol storage section 32 is formed last time, and it is hard decision transmitting symbol b^n. As a channel value is presumed using (k), that presumed precision can be raised.

[0108] Signal un of N sequence which carried out identification separation of the interference [train / other-system] for these to the sending signal of N sequence in the multi-output equalizer 71 of the preceding paragraph in the example shown in drawing 17 Channel information alphan after identification It outputs and is the signal un of after that and N sequences each. Latter single user equalizer 22-n removed the intersymbol interference of the same sending signal. That is, it considered as two steps of concatenation identification configurations. It is good also as three or more steps of concatenation multistage configurations. For example, input signal rm of an M sequence [as opposed to / in / as shown in drawing 21 / the equalizer 81 of the 1st step / the sending signal of N sequence] Identification signal sequence er1 which inputted and removed interference by the No. [U+1] transmitting sequence of the 1st - a No. [U] transmitting sequence (k) and channel information e[after the identification] alpha (k), Identification signal sequence er2 which removed interference by the 1st of the U+1st - a No. [N] transmitting sequence - the No. [U] transmitting sequence (k) and channel information ealpha2 after the identification (k) is obtained. In 82-1 in the equalizer 82-1 of the 2nd step, and 82-2 inputted er1 (k) and ealpha1 (k) — identification processing — carrying out — the [the 1st in the 1st - a No. / U / transmitting sequence -] — U1 the Uth of a watch transmitting sequence — identification signal sequence er3 which removed interference by 1+1 - the No. [U] transmitting sequence Channel information ealpha3 after (k) and its identification With (k) the Uth in the 1st - a No. [U] transmitting sequence — the [1+1 -] — U2 the [1st / of a watch transmitting sequence / the / -] — the [U No. 1 transmitting sequence and] — identification signal sequence er4 which removed interference by U2 - the No. [U] transmitting sequence Channel information ealpha4 after (k) and its identification With (k) the Uth in the 1st - the Uth transmitting sequence — the [the 1st of 2+1 - the Uth transmitting sequence -] — U2 Identification signal sequence er5 which removed interference by the transmitting sequence Channel information ealpha5 after (k) and its identification (k) is outputted, respectively.

[0109] With the equalizer 82-2 of the 2nd step, it is the identification signal sequence er2 similarly. (k) and channel information ealpha2 (k) is inputted and it is the identification signal sequence er6. (k) and channel information ealpha6 after identification (k) and identification signal sequence er7 (k) and channel information ealpha7 after identification (k) is outputted. In the case of N= 5, the equalizer 83-1 to 83-5 of the 3rd step turns into a single user equalizer in drawing 18 . Or the input identification signal of an equalizer 83-3 may be constituted by two sending signals, may remove the mutual intervention between the two sending signals with an equalizer 83-3, and may equalize 2 sets of identification signals, and the channel information after the identification, respectively by the following single user equalizer 84-1 and 84-2. Furthermore, for example with an equalizer 83-4, it is the identification signal er6. (k) and channel information ealpha6 (k) may be inputted and a mutual intervention with other two sending signals and the

intersymbol interference by the multi-pass of itself may be removed about all the configuration sending signals, for example, each of three sending signals. You may constitute from one thru/or the plurality of the equalizer 82-1 of the 2nd step, and 82-2 so that each identification signal over two or more sending signals may be acquired at once.

[0110] Generally two or more identification signal sequences and the group of after [identification] channel information are outputted from the equalizer of the 1st step as mentioned above. the group of the channel information after each identification signal sequence and its identification — 1 thru/or two or more equalizers — 1 — or two or more steps are concatenated — making — final — the 1- each identification output of the Nth transmitting sequence, i.e., this example, — a logarithm — likelihood ratio lambda 1 [bn (k)] can also be made to output. Thus, when performing multistage concatenation identification processing, it is desirable for the latter part to make smallness the value of numbers-of-passes Q which carries out interference removal, as mentioned above, and to lessen the amount of data processing. In this case, as mentioned above, an interferent component with the pass which decreased in number in the latter part is removed in the identification stage in front of that.

[0111] In the following with the equalizer 21 of the 1st step in drawing 21 The transmitting sequence of N individual, the number of the multi-passes of each transmitting sequence — identification signal sequence er1 of the group of the input signal of Q to U transmitting sequences Channel information ealpha1 after (k) and identification (k) is obtained and identification processing with the equalizer 82-1 of the latter part explains the identification processing in the case of making the number of the multi-passes of each transmitting train system into Q'. Although interference vector B' (k) is generated in the interference vector generation section 72 almost like the example shown in drawing 18 and drawing 19 , this constructive mood (53) and a formula (54) change into formula (53) and formula (54) ' and a formula (73).

[0112]

b'(k+q) =[b'1 b(k+q) '2 — (k+q) b'n (k+q)

— b'N (k+q)]T : q=Q -1, —1 (53)

b'(k+q) = [0 —0 b' U+1 (k+q) —b'N] (k+q) T : q= 0, —, -Q'+1 (54) ' b'(k+q) =[b'1 b(k+q) '2 — (k+q) b'n (k+q)

— b'N (k+q)]T : q=Q', —, -Q+1 (73) Formula (54) ' is for equalizing except for the self and the mutual intersymbol-interference component of each [these] sequence based on the symbol of the 1st - the Uth transmitting sequence itself, and the multi-pass of Q'. A formula (73) is for removing the self and the mutual intersymbol interference of the 1st - the Uth transmitting sequence based on the Q'+1st thru/or the Qth pass in order to decrease the number of multi-passes to Q' by latter identification.

[0113] Thus, interference signal replica H-B' (k) is made using obtained interference vector B' (k), and this is subtracted from receiving vector y (k), that is, a degree type is calculated.

y'g (k) **y(k)-H-B' (k) Actuation of subtracting this interference below (27) ″ =H-(B(k)-B' (k)) +n (k) and (28)″ will be called software interference cancellation. y'g which will be obtained after subtraction supposing replica H-B[of an interference signal] ' (k) is made ideally It turns out that (k) cannot have only the signal component of bn (k), [bn (k-1), —, bn] (k-Q'+1), and (n=1-U). [the symbol of the 1st - the Uth transmitting sequence,]

[0114] Next, the linearity filter of an MMSE norm removes the interference surplus component after software interference cancellation like the above-mentioned. The formula in this case (55) and the corresponding formula become degree type (55) '.

wg H (k) and y'g (k) **sigman=1 U sigmaq=0 Q'-1alphanq(k) and bn =(k-q) alphag H (k) and bg (k) (55) ' — here, alphag (— k —) — = — [— alpha — one — zero — (— k —) — alpha — one — Q — ' - one — (— k —) — alpha — U — zero — (— k —) — alpha — U — Q — ' - one — (- - k —) —] — T — (55-1)

bg (— k —) — = — [— b — one — (— k —) — b — one (k-Q'+1) — bU — (— k —) — bU —] (k-Q'+1) — T — (55-2)

These [wg] (k) and alphag wg from which the right-hand side serves as min by making a formula (56) into a degree type like [also asking for (k)] the above-mentioned (k) and alphag It asks for

(k).
[0115]
(wg (k) alphag (k)) =arg min ||wg H (k) and y'g (k)-alphag H (k) and bg (k) ||2 (56) 'alpha — 1 and 0 It is contingent [on (k) =1]. the added constraint — alphag (k) =0 and wg (k) =0 — in order to avoid a solution — it is — ||alphag (k) ||2 =1 — although solving by the constraint is also possible — the following — alpha — 1 and 0 In the case of (k) =1, a problem is replaced as follows.
mg (k) =arg min ||mg H (k) and zg (k) ||2 (57) 'mg H It is contingent [on (k) and eMQ'+1 =-1]. Here, it is mg. (k) **[wg T (k)-alphag T (k)] T (58) ' zg (k) **[yg T (k) b(k) g T] T (59) ' eMQ'+1 = [0 — 1 — 0] T (60) ' (eMQ' +1 element of inner one MQ' the +1st)
The solution of this optimization problem is given below from the Lagrange method of undetermined coefficients shown in said reference [2].
[0116]
mg (k) =-Rzz-1 and eMQ'+1/(eMQ'+1 H, Rzz-1, and eMQ'+1) [(61) ' — here — 0117]
[Equation 25]

$$R_{zz} = E[\, Z_g(k) \cdot Z_g^H(k)] \qquad (62)'$$

$$= E\begin{bmatrix} H \cdot \Lambda(k) \cdot H^H + \sigma^2 I & H_g^H \\ H_g & I \end{bmatrix} \qquad (63)'$$

[0118]
lambdan (k) =diag [Dn (k+Q -1), —, Dn (k), —, Dn] (k-Q +1) (64) ' [0119]
[Equation 26]

$$H_g = \begin{bmatrix} h_1(Q-1) & 0 & 0 & \cdots & h_U(Q-1) & 0 & 0 \\ h_1(Q-2) & \ddots & 0 & \cdots & h_U(Q-2) & \ddots & 0 \\ h_1(Q-3) & \vdots & h_1(Q-1) & \cdots & h_U(Q-3) & \vdots & h_U(Q-1) \\ \vdots & \vdots & \vdots & \cdots & \vdots & \vdots & \vdots \\ h_1(0) & \cdots & h_1(Q'-1) & \cdots & h_U(0) & \cdots & h_U(Q'-1) \end{bmatrix} \qquad (65)'$$

[0120]
Dn =(k+q) diag [1-b'1 2 (k+q), —, 1-b'n 2 (k+q), —, 1-b'N 2] (k+q) : q=Q+ — 1, —, 1 (66)
Dn =(k+q) diag [1, —, 1, and 1-b'U +12 (k+q), —, 1-b'N 2] (k+q) : q= 0, —, -Q'+1 (67) ' Dn =(k+q) diag [1-b'1 2 (k+q), —, 1-b'n 2 (k+q), —, 1-b'N 2] (k+q) : q=Q', ——Q+1 (74)
That is, it is mg if a channel parameter is known. It can ask for (k) by formula (61) '. Furthermore, formula (58) ' is followed and it is wg. (k) and alphag (k) and (=ealpha1 (k)) are called for. Such count is performed in the filter shape presumption section 76 in drawing 19 , and filtering of the degree type is calculated and carried out in the filtering section 77-1.
[0121]
er1 (k) =wg H (k) and y'g (k)
This identification output er1 (k) and after [identification] channel information ealpha1 (k) =alphag (k) is sent to the latter equalizer 82-1. When dividing [for example,] into a 3 transmitting sequences (user) group and a 2 transmitting sequences (user) group as mentioned above at the time of the transmitting sequence (user) of 5 It reaches U=3, the above-mentioned algorithm is performed by 2, and they are these two identification outputs er1. (k), ealpha1 (k) and er2 (k) and ealpha2 It inputs into the equalizer the object for 3 transmitting sequences (user) of consecutiveness to (k), and for 2 transmitting sequences (user), and the identification output of each transmitting sequence (user) is obtained, respectively.
[0122] Moreover, it is applicable also to the single user turbo equalizer receiver shown in drawing 8 , the RAKE composition processing turbo receiver shown in drawing 9 , a turbo receiver equipped with the adaptive array antenna receive section which showed drawing 10 , and a turbo receiver equipped with the channel presumption machine 42 still more generally shown in drawing 12 to make the error correction decode result of the signal which was mentioned above and to

detect reflect in a soft decision transmitting symbol. Furthermore, although the symbol hard decision value judged to be probable by presumption of the 2nd henceforth of the channel matrix H and covariance-matrix U^ was also used as a reference sign in drawing 13 , drawing 14 , and drawing 15 , 2nd henceforth may make only unique WORD a reference sign, covariance-matrix U^ may be presumed using a formula (51), and channel presumption using a symbol hard decision value and presumption of covariance-matrix U^ may be omitted.
the 1st invention (2) (juxtaposition transmission) — transmitting information sequence c (i) by one user as two or more juxtaposition sequences next — frequency use — performing high-speed transmission efficiently is proposed. The example of the turbo receiver which applied this invention is explained to such a sending signal.
[0123] It sets to a transmitting side so that the same reference mark may be attached with drawing 1 at the part corresponding to drawing 22 and it may be shown. As for modulation output-signal [from a modulator 13] b (j), the sequential distribution of the each symbol b (j) are carried out by the serial-parallel transducer 14 at the sequence of N individual. Sequence signal b1 of two or more integer N individuals (k), —, bN Although it is referred to as (k) and shown in drawing, after these are changed into the signal of a radio frequency, they are transmitted from the antenna of N individual. The sequence signal of these N individual is received by the turbo receiver of this invention through a channel (transmission line). the receiving antenna of this receiver — one or more pieces — it is — this input signal — baseband digital input signal rm of one or more integers [M] (k) — (— m= — it is inputted into the multi-output equalizer 31 as 1, 2, —, M). Input signal rm (k) is generated as shown in drawing 28 .
[0124] The processing the multi-output equalizer 31 is the same as that of the configuration shown in drawing 2 , and same as the procedure shown in drawing 3 is performed. the logarithm from the decoder 24 shown in drawing 22 on that occasion — likelihood ratio lambda 2 [b (i)] to external information lambda 1 [bi] is subtracted with a subtractor 25. The interleave of the subtraction output is carried out by INTARIBA 26, and it is the prior information lambda 2. It is referred to as [b (j)]. The prior information lambda 2 [b (j)] is the prior information lambda 2 on N sequence at the serial-parallel converter 15. [b1 (k)], —, lambda 2 It is changed into [bN (k)] and is inputted into the multi-output equalizer 31.
[0125] therefore, in the multi-output equalizer 31, the input signal of the M sequence carries out linear equalization processing similarly with having stated previously — having — the logarithm of N individual — likelihood ratio sequence lambda 1 [b1 (k)], —, lambda 1 [bN (k)] is outputted. the logarithm of this N individual sequence — a likelihood ratio sequence — the juxtaposition-serializer 16 — the logarithm of one sequence — likelihood ratio sequence lambda 1 It is changed into [b (j)] and a subtractor 22 is supplied. By identification processing which the input signal format of the multi-output equalizer 31 became being the same as that of what was explained by drawing 1 thru/or drawing 3 according to this configuration, therefore was performed with reference to drawing 1 thru/or drawing 3 the logarithm of N sequence — likelihood ratio lambda 1 [b1 (k)], —, lambda 1 He can obtain [bN (k)] and it will be easily understood by using the serial-parallel converter 15 and the parallel-serial-conversion machine 16 that decode processing can be performed repeatedly. In drawing 1 thru/or drawing 3 , identification of the n-th sending signal (eye n train) in the juxtaposition sending signal of N individual will be carried out in this case corresponding to the sending signal of the n-th transmitter. Moreover, it can be understood easily that the example which referred to drawing 4 thru/or drawing 7 R> 7 is also applicable about the reception to juxtaposition transmission of this N sequence signal. Moreover, by concatenation-processing by two or more identification stages shown in drawing 18 thru/or drawing 21 , a receiving property improves compared with processing by the single identification stage shown in drawing 1 thru/or drawing 31 :
[0126] The turbo receiving approach of this invention and a receiver are applicable also to the reception to a convolutional code / turbo sign + INTARIBA + multi-level modulation (QPSK, 8PSK, 16QAM, 64QAM, etc.), the TCM (Trellis Coded Modulation)/turbo TCM, etc.
By generation **** of M input signals, they are M input signals r1. (k), —, rM Although it asked for (k) from M antenna #1, —, #M, you may ask from one antenna or may ask for many M input signals from L from the input signal of the antenna of two or more integers [L]. although

drawing 1 was not especially shown — each — the input signal from antenna #1, —, #M — a baseband transducer — input signals r1, —, rm of baseband ** — it is carried out and samples – – having — digital signal r1 of the discrete time of day k (k), —, rM It is referred to as (k).
[0127] For example, the input signal received by L= 2 antenna #1 and #2 as shown in drawing 30 B is changed into baseband signaling by the baseband transducer 61-1 and 61-2, respectively. The baseband transducer 61-1 and each output of 61-2 the sampling signal and this sampling signal from the sampling signal generator 62 with the sampling signal which shifted the phase only T/2 of those periods T with the phase shifter 63 It is sampled by A/D converter 64-1, 64-2 and 64-3, and 64-4, respectively, and is a digital signal r1. (k), r2 (k) and r3 (k) and r4 It is changed into (k), and is inputted into the turbo receiver 30 shown in drawing 1 , drawing 18 , or drawing 22 , and you may make it obtain the decode output of N individual. In addition, input signal r1 inputted into the turbo receiver 30 (k), —, r4 Each sampling period of (k) is one input signal rm per one antenna. The frequency of the sampling signal from the sampling signal generator 62 is selected so that it may be in agreement with the sampling period in the case of receiving (k).
[0128]
[Effect of the Invention] As stated above, according to this 1st invention (1), the multi-output (MIMO) receiving approach is realizable. An error rate property is shown in drawing 23 and drawing 24 as quantitive effectiveness. It sets to each drawing and they are Eb of an axis of abscissa / No. It is a bit energy pair noise ratio. The following was assumed as simulation conditions.
several users (transmitter) — N 2 Each user's number Q of multi-passes 5 The number of receiving antennas Two The number of information symbols in one frame 450 bits Unique numbers of words in one frame 25 bits The channel presuming method RLS (oblivion multiplier 0.99)
Error correcting code Rates 1/2, restricted length 3 convolutional code
Doppler frequency 1000Hz (Rayleigh fading)
modulation technique BPSK Transmission speed 20Mbps Decoder 24 Max-Log-Map decoder The number of repeats 4 times The approximation by the lemma of said inverse matrix was not used for count of filter factor w without phasing within a frame.
[0129] the error rate property when, as for drawing 23 , channel presumption being performed completely (a presumed error being nothing), that is, assuming that a channel is known — it is — several users (transmitter) — N= 2 and several receiving antennas — it is the case of M= 2 and the Raylegh numbers of passes Q= 5. The 1st repeat is in the condition which has not been carried out repeatedly, and is the result of performing a repeat once by the 2nd repeat. It turns out that the error rate property is sharply improved by the repeat. Thereby, it turns out that the turbo receiving approach for MIMO of this invention operates appropriately.
[0130] Drawing 24 shows the effectiveness of repeat channel presumption (the 4th invention). An axis of abscissa is threshold Th. It fixes to Eb/No =4dB (Eb is a part for one user), and, as for Th=1.0, one is considered to be the conventional method with which channel presumption using [choose that is,] a symbol hard decision value is not performed for a symbol hard decision value. In this case, since channel presumption is inaccurate, there is little repeat effectiveness of a BER property, so that clearly from drawing. Threshold Th=0 is the case where a hard decision value is all used as it is, if the hard decision value of an information symbol also uses in this way, an average bit error rate will be improved so that clearly from drawing, and it is understood that channel presumption can carry out correctly so much. Furthermore, about threshold Th=0.2-0.6, it turns out that it is better to use [whose average bit error rate serves as smallness from the case of Th=0] only a probable hard decision value. It is understood especially that the Th=0.25 neighborhood is also the most desirable.
[0131] A probable transmitting symbol hard decision value is used for drawing 25 with a threshold at channel presumption, that is, a threshold in case [this] the error rate property of the MIMO receiving approach using repeat channel presumption is shown as a curve 66 is set as 0.25, and a result is the property of 4 times after repeatedly, and are N= 2, M= 2, Q=5Raylegh, fd Ts =1/20000, and 900 symbols / frame. The error rate property when the hard decision value of

the conventional information symbol not using an error rate property when channel presumption is perfect for channel presumption for a comparison, that is, using channel presumption (channel presumption being only for 1 time) without a repeat for a curve 67 is shown in a curve 68. When repeat presumption of a channel is used from this graph, it turns out that the error rate property is approaching it in the case of channel presumption completeness.

[0132] Moreover, according to the channel presumption approach mentioned above, by judging whether a soft decision value to the decoded hard decision value is probable, and using the probable symbol information on a hard decision value for channel presumption in the case of next repeat reception, channel presumption can be performed more correctly and decode quality can be improved. Next, in order to check the effectiveness of an example of having presumed covariance-matrix U^ (noises other than Gaussian characteristic noise), simulation was performed on condition that the following.

several users (transmitter) of all -- N 3 (one user is set to strange interference:i (k) inside)
Each user's number Q of multi-passes 5 The number of receiving antennas Three The number of information symbols in one frame 450 bits Error correcting code Rates 1/2, restricted length 3 convolutional code
Doppler frequency 1000Hz Modulation technique BPSK Transmission speed 20Mbps Decoder 24 Log-MAP is a decoder. The number of repeats Three users (transmitter) were taken as ****** 4 times. The simulation result of the BER (bit error rate) property of H which showed drawing 26 to drawing 14 , drawing 15 , and drawing 16 , and the turbo receiver which presumes U^, and drawing 27 show the BER property using the turbo receiver (receiver using the approach of drawing 13) shown in drawing 1 as it is. what improvement in a BER property is attained and BER moreover shows to drawing 26 to the same Eb/No by making [many] a number repeatedly in drawing 27 although the effectiveness is hardly acquired in drawing 26 even if it is making the noise only into the white nature Gaussian random noise and repeats channel presumption and decode processing twice or more -- ****** -- it is understood that a small value is shown.

[0133] Next, symbol soft decision value b'n of the input signal from the target user (transmitter) In order to check the effectiveness of the example (the 2nd invention) in which the error correction decode result was made to reflect to (k), simulation was performed on condition that the following.

user (transmitter) several N [all] 4 Each user's number Q of multi-passes 5 The number M of receiving antennas 2 Number of information symbols in one frame 900 Error correcting code Convolutional code (the rate of coding: one half, restricted length 3)
Modulation technique BPSK Decoder Log-Map decoder Rate of error coding 1/2 The number of repeats 5 It is f(b'n (k)) = alphaxb'n again. (k)
It carried out.

[0134] Drawing 28 is [the multi-output turbo receiver shown in drawing 1 , and] b'n. The former is black about a plotting point and the latter shows in white the BER property of a multi-input multi-output turbo receiver of having made the error correction decode result reflecting in (k), respectively. As for a round head, in the 3rd leftward trigonum, the 4th rightward trigonum expresses [the 1st downward trigonum / the 2nd rhombus] the 5th time repeatedly. The simulation result of the BER property over Eb/No when fixing drawing 28 A to alpha= 0.2 and drawing 26 B show the simulation result of the BER property over alpha when being referred to as Eb/No=6dB, respectively. In the case of alpha= 0, it is b'n here. It is equal when referred to as (k) =0. From this drawing 28 A, it is b'n. In the multi-input multi-output receiver which made the error correction decode result reflect in (k) When the count of a repeat is 3rd henceforth compared with the multi-input multi-output turbo receiver shown in drawing 1 , an improvement effect is large to BER at the time of repeat decode 1 time ago. Necessary Eb / N0 to which the count of a repeat attains each BER in the range of BER>10-4 3rd henceforth When it compares, b'n Compared with the multi-input multi-output turbo receiver which showed the multi-input multi-output turbo receiver which made the error correction decode result reflect in (k) to drawing 1 , gain about 0.5dB or more is acquired. Moreover, in the 5th Eb/No=6dB repeat, it turns out that BER=10-5BER is attained and BER can be reduced or less to 1/10 compared with what was shown in drawing 1 . From this drawing 2828 B, as a value of alpha, the improvement is

obtained in 0< alpha<0.6, if alpha is made larger than 0.6, a BER property will deteriorate conversely and a right decode result will no longer be obtained. This result shows that the optimum value of alpha in this case is 0.2. However, the value of alpha is not restricted to said optimum value, and the proper range of alpha which has an improvement effect may be changed by the number of the number of the users who receive especially, a propagation environment including interference, and the antennas to receive etc., and the value of an optimum value alpha may also take other values.

[0135] According to [although it is 2 Ns (Q-1) order as stated previously] the turbo receiving approach of the 3rd invention, the computational complexity in the equalizer at the time of setting [the number of users (transmitter)] the number of the antennas of Q and a receiver to M for the number of N and the multi-passes of each transmitter, and extending the turbo receiver of the conventional single user to many outputs (MIMO) as it was in a BPSK modulation is N (MQ)3. It ends with order. For example, although it is 2N(Q-1) **5x1045 when N= 8, Q= 20, and M= 8, it is N(MQ)3 **37 and 107. It becomes, and according to the turbo receiving approach of this 2nd invention, computational complexity can be reduced remarkably.

[0136] According to the turbo receiving approach of this 3rd invention, on condition that the following, simulation was performed and it checked that a good bit error rate property was acquired. The channel matrix H was made into known.

The number N of users 4 Each user's number Q of multi-passes 5 The number M of receiving antennas Two The number of information symbols in one frame 900 bits Error correcting code Rates 1/2, restricted length 3 convolutional code

Doppler frequency 1000Hz (Rayleigh fading)

Modulation technique BPSK Transmission speed 20Mbps Decoder Log-MAP decoder The number of repeats 6 times Channel presumption shows the simulation result of this BER (bit error rate) property to ideal drawing 29 . Axes of abscissa are average Eb / (bit energy) No (noise power), fd is the Doppler frequency and Ts is a transmitting symbol period. MRC shown in this graph is a BER property acquired when Viterbi decoding of the signal after the maximum ratio composition (Maximal Ratio Conbining:MRC) in an order 10 (2 antenna x5 pass) diversity channel is carried out, and corresponds to the BER property at the time of an equalizer canceling interference completely. That is, whether BER of which after a repetition is close to a MRC curve can estimate the quality of a receiver. According to the turbo receiving approach of this 2nd invention by drawing 27 , they are Eb/No. If BER decreases and the count of a repeat is made [many] so that it becomes high, it turns out that a BER property approaches the BER property of MRC and MRC is especially approached very much by the count 6 of a repeat. That is, it was checked that the multi-output turbo receiver by the turbo receiving approach of this 3rd invention operates appropriately also on the severe conditions of four users, five pass each, and 2 receiving antennas.

[Translation done.]

TECHNICAL FIELD

[Field of the Invention] This invention is applied to mobile communication and relates the waveform distortion based on interference to the turbo receiving approach of having applied the turbo sign technique and of performing identification repeatedly, and its receiver.

[Translation done.]

PRIOR ART

[Description of the Prior Art] The technical problem of a mobile phone service is [how] quality on the limited frequency, and it is in whether the system which can own many users is built. There is a multi-input multi-output (Multi-Input Multi-Output:MIMO) system as a means to solve such a technical problem. This system configuration as shown in drawing 3030 A From two or more transmitters S1-SN to this time of day Symbol c1(i) -cN(i) is transmitted on this frequency, respectively. These sending signals A MIMO receiver equipped with two or more antenna #1 - #M receives, and a MIMO receiver processes an input signal, presumes transmitting symbol c1(i) -cN(i) of each transmitters S1-SN, and outputs it to an output terminal Out1 - OutN separately as c1^ (i) - cN^ (i).
[0003] Examination about the concrete construction of the MIMO receiver in a MIMO system is not fully performed the place to current. the number of multi-passes with which N and the transmitted electric wave of each transmitter reach a MIMO receiver in the number of transmitters when performing the configuration of the MIMO receiver in a MIMO system based on a MLSE (maximum likelihood estimation) norm — the computational complexity of Q, then a MIMO receiver — 2(Q-1) N a digit — becoming — several transmitters — the computational complexity will become immense with the increment in N and the number Q of multi-passes. Moreover, when receiving that to which the information on a single user was transmitted as two or more parallel signals, much computational complexity is needed for separating each parallel signal with the increment in the number of multi-passes. Then, although this invention proposes the turbo receiving approach of two or more sequences signal with sufficient count effectiveness, it explains the turbo receiver to the existing single user which becomes origin of this invention first (one transmitter), i.e., 1 sequence sending signal.
[0004] turbo ****** for single users — the example of a configuration of the transmitter in this case and a receiver is shown in drawing 31 . In a transmitter 10, after coding of information sequence c (i) is performed by the encoder 11 and the interleave (rearrangement) of the coding output is carried out by INTARIBA 12, a carrier signal is modulated with a modulator 13 and the modulation output is transmitted. This sending signal is received by the receiver 20 through a transmission line (each channel of a multi-pass). Identification of a delay wave is performed by the ************ (SISO:Single-Input-Single-Output) equalizer 21 in a receiver 20. Generally an input signal is changed into baseband, and the input signal of that baseband is sampled on the frequency of 1 time or more of the frequency of the symbol signal of the information sequence of a sending signal, and the input of this equalizer 21 is changed into a digital signal, and is inputted into an equalizer 21 as an input signal of a digital signal.
[0005] Reception output [in / in the case of a single user, N= 1 is hit in drawing 30 A, and / each receiving-antenna #m (m= 1, 2, —, M)] rm (k) = sigmaq=0 Q-1 hm (q) -b(k-q)+vm (k) (1) It can express. For m, an antenna index and h are [a user's (transmitter 1) transmitting symbol and vm (k) of a channel value (transmission-line impulse response: line characteristic) and b (k-q +1)] the thermal noise inside a receiver 20. And the output from all antenna #1-#M is expressed as a vector of a formula (2), and it is a formula (3).
r(k) = [r1 (k) r2 (k) —rM (k)] T (2)
= sigmaq=0 Q-1 H (q) -b(k-q +1) +v (k) (3)

A definition is given. here — v (k) = — [— v — one — (— k —) — v — two — (— k —) — vM — (— k —) —] — T — (4)
H (q) = [h1 (q) —hM (q)] T (5)
It comes out. Moreover, [ ] T A transposed matrix is expressed. Next, the following vectors and matrices are defined in consideration of several Q of a multi-pass (channel).
[0006]
y(k) ** [rT rT (k+Q -1) —(k+Q -2) rT (k)] T (6)
**H-b (k) +n (k) (7)
It is here and is [0007].
[Equation 13]

$$H=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & \ddots & \\ 0 & & H(0) & \cdots H(Q-1) \end{bmatrix} \qquad (8)$$

[0008] However, b(k-q) =[b(k+Q -1) b(k+Q -2) —b (k-Q +1)] T (9)
n (k) = [vT vT (k+Q -1) —(k+Q -2) vT (k)] T (10)
It comes out. the logarithm of the probability for r (k) which the top defined to be inputted into an equalizer 21, for this SISO equalizer 21 to be a linear equalization machine, and for each coding bit {b (i)} to be +1 as that identification output, and the probability which is -1 — a likelihood ratio lambda 1 (LLR:Log-LikelihoodRatio) is drawn.
[0009]
[Equation 14]

$$\Lambda_1[b(k)]=\log\frac{\Pr[b(k)=+1\,|\,y(k)]}{\Pr[b(k)=-1\,|\,y(k)]} \qquad (11)$$

$$\equiv \lambda_1[b(k)]+\lambda_2^p[b(k)] \qquad (12)$$

[0010] It comes out. It is lambda 1 here. [b (k)] is the external information and lambda2p which are sent to the consecutive decoder 24. [b (k)] is prior information given to an equalizer 21. a logarithm — likelihood ratio lambda 1 [b (k)] — prior information lambda 2 [b (k)] is subtracted with a subtractor 22, and is further supplied to the SISO channel decoder 24 through DEINTARIBA 23. this decoder 24 — a logarithm — a likelihood ratio lambda 2 and [0011]
[Equation 15]

$$\Lambda_2[b(i)]=\log\frac{\Pr[b(i)=+1\,|\,\lambda_1[b(i)],i=0,\cdots,B-1]}{\Pr[b(i)=-1\,|\,\lambda_1[b(i)],i=0,\cdots,B-1]} \qquad (13)$$

B：フレーム長

$$\equiv \lambda_2[b(i)]+\lambda_1^p[b(i)] \qquad (14)$$

[0012] It computes. It is lambda 2 here. [b (i)] is lambda2 p to an equalizer 21 in the case of a repeat. It is the external information given as [b (k)], and is lambda 1. [b (k)] is prior information lambda1 p to a decoder 24. It is given as [b (i)]. lambda 2 [b (i)] is lambda 1 with a subtractor 25. [b (i)] is subtracted and an equalizer 21 and a subtractor 22 are supplied through INTARIBA 26. Thus, identification and decode are performed repeatedly and improvement in an error rate is attained. Next, calculation of the linearity filter shape given to receiving vector y (k) as a detail of the equalizer 21 of the preceding paragraph is described. prior information lambda2 p of an equalizer 21 [b (k)] — using — soft decision symbol estimate b'(k) =tan h[— lambda2 p — [b (k)]/2] (15)
It computes. And replica H-b[of an interferent component, i.e., an interferent component,] ' (k) is reproduced using this estimate and the channel matrix H, and it subtracts from an input signal. It is got blocked. y'(k) **y(k)-H-b' (k) (16)
= H-(b(k)-b' (k)) +n (k) (17)
It is here. b'(k) = [b'(k+Q -1) —0 —b' (k-Q +1)] T (18)

It calculates. Since replica H-b[of an interferent component] ' (k) is not necessarily an exact replica, it cannot remove an interferent component completely by the formula (16). Then, it asks for linearity filter factor w (k) which erases the remainder of an interferent component by the following MMSE (2nd [an average of] power error of the minimum) norms.

[0013]

w(k) =arg min ||wH (k) and y'(k)-b(k) ||2 (19)

H expresses conjugation transposition and is ||. || expresses a norm. It asks for w (k) which makes a formula (19) min. the following derivation of w (k) -- reference: -- it is indicated by Daryl Reynolds and Xiaodong Wang and "LowComplexity Turbo-Equalization for Diversity Channels" (http:/ee.tamu.edu/reynolds/). There is drastic reduction of computational complexity as main achievement matters of this technique. The computational complexity of the conventional MLSE mold turbo is 2Q-1. This technique is Q3 to having been proportional to order. It is stopped by order. In addition, wH (k) -y' (k) is the output of an equalizer 21 and is lambda 1 after this. [b (k)] is calculated, a decoder 24 is supplied through DEINTARIBA 23, and a decode operation is performed.

[0014] In order to perform identification processing in an equalizer 21, it is necessary to presume the channel value h (transmission-line impulse response) in a formula (1). Below, presumption of this channel value is described as channel presumption. Channel presumption is performed using the training sequence remembered to be the input signal of known training sequences, such as unique WORD sent to the head section in one frame. If the precision of channel presumption is bad, identification processing with an equalizer 21 will not be performed correctly. Although what is necessary is just to enlarge the rate that the training sequence in one frame occupies the precision of channel presumption to make it high, if it is made such, the transmission efficiency over original data will fall. Therefore, to make small the rate that the training sequence in one frame occupies, and to raise channel presumption precision is desired.

[0015] This has the same problem in the channel presumption in not only the receiver to the multi-sequence sending signal containing MIMO but a lake (RAKE) receiver, or the receiver which raises the probability of a decode result by decode processing repeatedly also in the receiver using an adaptive array antenna.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] As stated above, according to this 1st invention (1), the multi-output (MIMO) receiving approach is realizable. An error rate property is shown in drawing 23 and drawing 24 as quantitive effectiveness. It sets to each drawing and they are Eb of an axis of abscissa / No. It is a bit energy pair noise ratio. The following was assumed as simulation conditions.
several users (transmitter) — N 2 Each user's number Q of multi-passes 5 The number of receiving antennas Two The number of information symbols in one frame 450 bits Unique numbers of words in one frame 25 bits The channel presuming method RLS (oblivion multiplier 0.99)
Error correcting code Rates 1/2, restricted length 3 convolutional code
Doppler frequency 1000Hz (Rayleigh fading)
modulation technique BPSK Transmission speed 20Mbps Decoder 24 Max-Log-Map decoder The number of repeats 4 times The approximation by the lemma of said inverse matrix was not used for count of filter factor w without phasing within a frame.
[0129] the error rate property when, as for drawing 23 , channel presumption being performed completely (a presumed error being nothing), that is, assuming that a channel is known — it is — several users (transmitter) — N= 2 and several receiving antennas — it is the case of M= 2 and the Raylegh numbers of passes Q= 5. The 1st repeat is in the condition which has not been carried out repeatedly, and is the result of performing a repeat once by the 2nd repeat. It turns out that the error rate property is sharply improved by the repeat. Thereby, it turns out that the turbo receiving approach for MIMO of this invention operates appropriately.
[0130] Drawing 24 shows the effectiveness of repeat channel presumption (the 4th invention). An axis of abscissa is threshold Th. It fixes to Eb/No =4dB (Eb is a part for one user), and, as for Th=1.0, one is considered to be the conventional method with which channel presumption using [choose that is,] a symbol hard decision value is not performed for a symbol hard decision value. In this case, since channel presumption is inaccurate, there is little repeat effectiveness of a BER property, so that clearly from drawing. Threshold Th=0 is the case where a hard decision value is all used as it is, if the hard decision value of an information symbol also uses in this way, an average bit error rate will be improved so that clearly from drawing, and it is understood that channel presumption can carry out correctly so much. Furthermore, about threshold Th=0.2-0.6, it turns out that it is better to use [whose average bit error rate serves as smallness from the case of Th=0] only a probable hard decision value. It is understood especially that the Th=0.25 neighborhood is also the most desirable.
[0131] A probable transmitting symbol hard decision value is used for drawing 25 with a threshold at channel presumption, that is, a threshold in case [this] the error rate property of the MIMO receiving approach using repeat channel presumption is shown as a curve 66 is set as 0.25, and a result is the property of 4 times after repeatedly, and are N= 2, M= 2, Q=5Raylegh, fd Ts =1/20000, and 900 symbols / frame. The error rate property when the hard decision value of the conventional information symbol not using an error rate property when channel presumption is perfect for channel presumption for a comparison, that is, using channel presumption (channel presumption being only for 1 time) without a repeat for a curve 67 is shown in a curve 68. When

repeat presumption of a channel is used from this graph, it turns out that the error rate property is approaching it in the case of channel presumption completeness.
[0132] Moreover, according to the channel presumption approach mentioned above, by judging whether a soft decision value to the decoded hard decision value is probable, and using the probable symbol information on a hard decision value for channel presumption in the case of next repeat reception, channel presumption can be performed more correctly and decode quality can be improved. Next, in order to check the effectiveness of an example of having presumed covariance-matrix U^ (noises other than Gaussian characteristic noise), simulation was performed on condition that the following.
several users (transmitter) of all — N 3 (one user is set to strange interference:i (k) inside) Each user's number Q of multi-passes 5 The number of receiving antennas Three The number of information symbols in one frame 450 bits Error correcting code Rates 1/2, restricted length 3 convolutional code
Doppler frequency 1000Hz Modulation technique BPSK Transmission speed 20Mbps Decoder 24 Log-MAP is a decoder. The number of repeats Three users (transmitter) were taken as ****** 4 times. The simulation result of the BER (bit error rate) property of H which showed drawing 26 to drawing 14 , drawing 15 , and drawing 16 , and the turbo receiver which presumes U^, and drawing 27 show the BER property using the turbo receiver (receiver using the approach of drawing 13) shown in drawing 1 as it is. what improvement in a BER property is attained and BER moreover shows to drawing 26 to the same Eb/No by making [many] a number repeatedly in drawing 27 although the effectiveness is hardly acquired in drawing 26 even if it is making the noise only into the white nature Gaussian random noise and repeats channel presumption and decode processing twice or more — ****** — it is understood that a small value is shown.
[0133] Next, symbol soft decision value b'n of the input signal from the target user (transmitter) In order to check the effectiveness of the example (the 2nd invention) in which the error correction decode result was made to reflect to (k), simulation was performed on condition that the following.
user (transmitter) several N [all] 4 Each user's number Q of multi-passes 5 The number M of receiving antennas 2 Number of information symbols in one frame 900 Error correcting code Convolutional code (the rate of coding: one half, restricted length 3)
Modulation technique BPSK Decoder Log-Map decoder Rate of error coding 1/2 The number of repeats 5 It is f(b'n (k)) = alphaxb'n again. (k)
It carried out.
[0134] Drawing 28 is [the multi-output turbo receiver shown in drawing 1 , and] b'n. The former is black about a plotting point and the latter shows in white the BER property of a multi-input multi-output turbo receiver of having made the error correction decode result reflecting in (k), respectively. As for a round head, in the 3rd leftward trigonum, the 4th rightward trigonum expresses [the 1st downward trigonum / the 2nd rhombus] the 5th time repeatedly. The simulation result of the BER property over Eb/No when fixing drawing 28 A to alpha= 0.2 and drawing 26 B show the simulation result of the BER property over alpha when being referred to as Eb/No=6dB, respectively. In the case of alpha= 0, it is b'n here. It is equal when referred to as (k) =0. From this drawing 28 A, it is b'n. In the multi-input multi-output receiver which made the error correction decode result reflect in (k) When the count of a repeat is 3rd henceforth compared with the multi-input multi-output turbo receiver shown in drawing 1 , an improvement effect is large to BER at the time of repeat decode 1 time ago. Necessary Eb / N0 to which the count of a repeat attains each BER in the range of BER>10-4 3rd henceforth When it compares, b'n Compared with the multi-input multi-output turbo receiver which showed the multi-input multi-output turbo receiver which made the error correction decode result reflect in (k) to drawing 1 , gain about 0.5dB or more is acquired. Moreover, in the 5th Eb/No=6dB repeat, it turns out that BER=10-5BER is attained and BER can be reduced or less to 1/10 compared with what was shown in drawing 1 . From this drawing 2828 B, as a value of alpha, the improvement is obtained in 0< alpha<0.6, if alpha is made larger than 0.6, a BER property will deteriorate conversely and a right decode result will no longer be obtained. This result shows that the optimum value of alpha in this case is 0.2. However, the value of alpha is not restricted to said

optimum value, and the proper range of alpha which has an improvement effect may be changed by the number of the number of the users who receive especially, a propagation environment including interference, and the antennas to receive etc., and the value of an optimum value alpha may also take other values.
[0135] According to [although it is 2 Ns (Q−1) order as stated previously] the turbo receiving approach of the 3rd invention, the computational complexity in the equalizer at the time of setting [the number of users (transmitter)] the number of the antennas of Q and a receiver to M for the number of N and the multi-passes of each transmitter, and extending the turbo receiver of the conventional single user to many outputs (MIMO) as it was in a BPSK modulation is N (MQ)3. It ends with order. For example, although it is 2N(Q−1) **5x1045 when N= 8, Q= 20, and M= 8, it is N(MQ)3 **37 and 107. It becomes, and according to the turbo receiving approach of this 2nd invention, computational complexity can be reduced remarkably.
[0136] According to the turbo receiving approach of this 3rd invention, on condition that the following, simulation was performed and it checked that a good bit error rate property was acquired. The channel matrix H was made into known.
The number N of users 4 Each user's number Q of multi-passes 5 The number M of receiving antennas Two The number of information symbols in one frame 900 bits Error correcting code Rates 1/2, restricted length 3 convolutional code
Doppler frequency 1000Hz (Rayleigh fading)
Modulation technique BPSK Transmission speed 20Mbps Decoder Log-MAP decoder The number of repeats 6 times Channel presumption shows the simulation result of this BER (bit error rate) property to ideal drawing 29 . Axes of abscissa are average Eb / (bit energy) No (noise power), fd is the Doppler frequency and Ts is a transmitting symbol period. MRC shown in this graph is a BER property acquired when Viterbi decoding of the signal after the maximum ratio composition (Maximal Ratio Conbining:MRC) in an order 10 (2 antenna x5 pass) diversity channel is carried out, and corresponds to the BER property at the time of an equalizer canceling interference completely. That is, whether BER of which after a repetition is close to a MRC curve can estimate the quality of a receiver. According to the turbo receiving approach of this 2nd invention by drawing 27 , they are Eb/No. If BER decreases and the count of a repeat is made [many] so that it becomes high, it turns out that a BER property approaches the BER property of MRC and MRC is especially approached very much by the count 6 of a repeat. That is, it was checked that the multi-output turbo receiver by the turbo receiving approach of this 3rd invention operates appropriately also on the severe conditions of four users, five pass each, and 2 receiving antennas.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] The above-mentioned turbo receiver has the following technical problems.
- It is correspondence of only the sending signal of a single user (one set of transmitter), i.e., one sequence.
- In case an interferent component is reproduced, a channel value (matrix H) is required, and in case it is mounting, it is necessary to presume this.
The presumed error will degrade the effectiveness of identification repeatedly.
[0017] The purpose of this invention is to provide below with the turbo receiving approach which extended this object for reception to the receiver to two or more transmitting sequence signals, such as multiuser and ** single user juxtaposition transmission, and its receiver so that it may compensate these two points. Moreover, other purposes of this invention presume the channel value of an input signal from an input signal and the known signal as a reference sign. In the receiving approach of processing an input signal using the presumed channel value, performing decode processing to the processed signal, repeating processing and decode processing in which the channel value which carried out [above-mentioned] presumption was used to the same input signal, and performing them It is in offering the turbo receiving approach that a short paddle known signal can perform channel presumption with a sufficient precision comparatively, and its receiver.

[Translation done.]

MEANS

[Means for Solving the Problem] This 1st invention is the turbo receiving approach of receiving the sending signal of N sequence (N is two or more integers). M input signals rm (m= 1, --, M), From the known signal of N sequence, the channel value hmn (q), and (n= 1, --, N) are calculated. Prior information lambda 2 on N sequence acquired by decode It is based on [bn (k)] and is soft decision transmitting symbol b'n. It asks for (k). The channel value hmn (q) and soft decision transmitting symbol b'n Interferent component H-B' (k) made by sending signals other than the sending signal of the intersymbol interference which the sending signal of n sequence eye itself makes, and n sequence eye is calculated using (k), and it is here, and is [0019].
[Equation 16]

$$H=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & & \ddots & \\ 0 & & H(0) & & \cdots H(Q-1) \end{bmatrix}$$

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix}$$

[0020] B' (k) =[b'T (k+Q -1) — b'T (k) — b'T(k-Q +1)]Tb'(k+q) =[b'1 (k+q) b'2 — (k+q) b'N (k+q)] Tq=Q -1 .... -Q+1 It is b'(k) =[b'1 at q!=0. (k) — 0 — b'N [(k)] T The zero of the element of (b'(k) by q= 0 n-ths),] Q is the number of the multi-passes of each sending-signal electric wave, q= 0, —, Q-1, and []. T expresses a transposed matrix.
[0021] this intersymbol-interference H-B' (k) — from receiving vector y (k) — deducting — difference — it asks for vector y' (k).
here — y — (— k —) — = — [— rT — rT (k+Q -1) — (k+Q -2) — rT — (— k —) —] — Tr — (— k —) — = — [— r — one — (— k —) — r — two — (— k —) — rM — (— k —) —] — T — a channel — a matrix — H — or — a reference sign — using — difference — for removing the residual interferent component in vector y' (k) adaptation filter coefficient wn to the input signal of the sending signal of n sequence eye (k) — asking — difference — vector y' (k) — the above-mentioned adaptation filter factor wn as the input signal [as opposed to / carry out filtering by (k) and / the sending signal of n sequence eye] by which interference removal was carried out — the logarithm of n sequence — a likelihood ratio is obtained. the logarithm of these N sequence — it decodes using a likelihood ratio.
[0022] the — two — invention — depending — if — the — one — invention — setting — q — = — zero — a case — b'(k) =[b'1 (k) —f(b'n (k)) —b'N (k)] Tb' (k) — an element — f (b'n (k) is the n-th) f ( ) is f(0) =0 and d{f (characterized by considering as the function which makes a variable b'n (k) which fills b'n (k)}/d{b'n (k)} >=0.). According to the 3rd invention, identification processing is divided into two or more steps, and is performed, and the latter part lessens the number of the sequences of an identification output.
[0023] According to this 4th invention, the channel value of an input signal is presumed from an

input signal and the known signal as a reference sign. In the turbo receiving approach of processing an input signal using the presumed channel value, performing decode processing to the processed signal, repeating processing and decode processing in which the channel value which carried out [above-mentioned] presumption was used to the same input signal, and performing them The probability of the decoded hard decision information symbol is determined from the value of the soft-decision information symbol, and the probability uses it for the reference sign of next channel presumption of the hard decision information symbol beyond a predetermined value.
[0024]
[Embodiment of the Invention] The example of the MIMO structure of a system by which this invention is applied to 1st invention (1) drawing 1 is shown. Transmitter S1 of N individual of a transmitting side — It sets to each of SN and is the information sequence c1. (i) — cN (i) is encoded by the encoder 11-1, —, 11-N, respectively. A modulator 13-1, —, 13-N are supplied as a modulating signal through INTARIBA 12-1, —, 12-N, a carrier signal is modulated by these modulating signals, and these coding output is a signal b1. (k), —, bN It is transmitted as (k). That is, sending signal b1 from Transmitters S1, —, SN (k), —, bN It is the case where (k) is the sending signal of N sequence.
[0025] Input-signal r (k) received by the multi-output receiver through the transmission line (channel) is inputted into the multi-output equalizer 31, and the signal received by the receiver is changed into baseband signaling, and the baseband signaling is sampled, for example with one half of the periods of the symbol period, is changed into a digital signal, and is inputted into an equalizer 31 as the digital signal. Moreover, let this digital signal be one or more integers [M]. For example, let the input signal from M antennas be the input signal of M digital signals. the logarithm of an equalizer 31 to N individual — likelihood ratio lambda 1 [b1 (k)], —, lambda 1 [bN (k)] is outputted. lambda 1 [b1 (k)], —, lambda 1 [bN (k)] is the prior information lambda 1, respectively. [b1 (k)], —, lambda 1 [bN (k)] is subtracted by the subtractor 22-1, —, 22-N, respectively. Through DEINTARIBA 23-1, —, 23-N, it is inputted into the ************ (SISO) decoder (channel decoder) 24-1, —, 24-N, respectively, and decodes. a decoder 24-1, —, the decode information sequence c'1 from 24-N (i), —, c'N while (i) is outputted — a logarithm — likelihood ratio lambda 2 [b1 (i)], —, lambda 2 [bN (i)] is outputted, respectively. lambda 2 [b1 (i)], —, lambda 2 [bN (i)] is lambda 1 by the subtractor 25-1, —, 25-N. [b1 (i)], —, lambda 1 [bN (i)] is subtracted, respectively. Furthermore, INTARIBA 26-1, —, 26-N are led, respectively, and it is lambda 2. [b1 (k)], —, lambda 2 The multi-output equalizer 31 and a subtractor 22-1, —, 22-N are supplied as [bN (k)], respectively.
[0026] Input signal rm from multiuser (two or more transmitters) (k), and (m= 1, —, M) are an input of an equalizer 31. rm (k) =sigmaq=0 Q-1 sigman=1 N hmn(q) and bn+(k-q) vm (k) (20)
It becomes what was added by the multiple user. q= 0, —, Q-1, and Q are y(k) **[rT rT (k+Q -1), if the number of the multi-passes of each transmitted electric wave and the same procedure as the case of a single user define vector y (k). — (k+Q -2) It is rT (k).
]T (21)
= H-B (k) +n (k) (22)
here — r(k) =[r1(k) —rM(k)] T [0027]
[Equation 17]

$$H=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & \ddots & \\ 0 & & H(0) & \cdots H(Q-1) \end{bmatrix} \qquad (23)$$

However, [0028]
[Equation 18]

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix} \qquad (24)$$

[0029]
B(k) =[bT (k+Q -1) — bT (k) — bT (k-Q +1)
]T (25)
b(k+q) = [b1 b(k+q)2 —(k+q) bN] (k+q) T q=Q -1, Q-2, —, -Q+1 (26)
It becomes. Next, in an interference removal step, it is assumed that the signal from the n-th user (transmitter) is a request now. the compound thing with interference which the signal of interference and the n-th user by the signal of users other than the n-th itself makes from this example using the soft decision symbol estimate of the signal from all users (transmitter), and the channel matrix (transmission-line impulse response value matrix) H, i.e., interference replica H-B', (k) — reproducing — as follows — y (k) to this interference replica — subtracting — difference — vector y' (k) is generated.
[0030]
y'(k) **y(k)-H-B' (k) (27)
= H-(B(k)-B' (k)) +n (k) (28)
It is here. B'(k) = [b'T(k+Q -1) —b'T(k) —b'T (k-Q +1)] T (29)
and — b'(k+q) =[b'1 b(k+q) '2 —(k+q) b'N] (k+q) T : q=Q -1, —, -Q+1, and q!=0 (30)
b'(k) = [b'1 (k) —0 —b'N (k)] T : q= 0 (31)
Zero in the element of b' (k) is the n-th. b'n (k) is b'n like a formula (15). It is the soft decision transmitting symbol estimate which calculated and calculated (k) =tan h [lambda2 [bn (k)]/2]. Vector B' (k) is the replica vector of an interference symbol.
[0031] Next, n-th filter factor wn for users for erasing the interference remainder based on the remainder of an interferent component, i.e., the incompleteness of interferent component replica H-B' (k), and the interferent component which the signal of the n-th self makes wn which makes the following formulas (32) min for (k) It asks for (k) by the MMSE (2nd [an average of] power error of the minimum) norm.
wn (k) =arg min ||wn H (k) and y'(k)-bn (k) ||2 (32)
The following actuation is the same as that of the case of a single user. That is, calculated wn (k) is used and it is wn H. (k) -y' (k) is calculated, DEINTARIBA 23-n is minded for the count result, and it is lambda 1. As [bn (i)], it inputs into decoder 24-n and a decode operation is performed.
[0032] It asks for filter (linear equalization) processing from the input signal rm by the above approach from a user 1 to N. As a result, the number of outputs of an equalizer 31 serves as N, and these outputs are decoded by each decoder 24-1, —, 24-N. The above is the escape for the multiuser (MIMO) of the turbo receiver for single users. From the above explanation, the example of a functional configuration of the multi-output equalizer 31 comes to be shown in drawing 2 . Receiving vector y (k) is generated by the receiving vector generation section 311, and M input signals rm (k) are supplied to the identification section 312-1 for every user - 313-N. Moreover, the channel matrix H calculated in the channel presumption machine 28 is supplied to the identification section 312-1 - 312-N. The prior information lambda 2 from each channel decoder 24-n [bn (k)] is inputted into the soft decision symbol presumption section 313, and it is soft decision transmitting symbol estimate b'n, respectively. (k) =tanh [lambda2 [bn (k)]/2] is calculated. The functional configuration and processing in the identification section 312-1 - 312-N are the same, are represented with the identification section 312-1, and are explained.
[0033] Furthermore, it is the estimate b'1 of a soft decision transmitting symbol. (k) - b'N (k) The interference replica vector generation section 314-1 is supplied, and it is the interference replica vector B'1 by formula (29) - (31). (k) is generated. this vector B'1 filtering of the (k) is carried out according to the channel matrix H in the filtering section 315-1 — having — interference replica component H-B' of that result — 1 (k) — the difference operation part 316-1 — receiving vector y1 it deducts from (k) — having — difference — vector y'1 (k) is generated.
[0034] The filter coefficient presumption section 317-1 is asked for the filter factor w1 the channel matrix H or for a reference sign being inputted so that it may mention later, and removing the remainder of said interferent component (k) at least. Filter factor w1 to which the channel matrix H from the channel presumption machine 28, covariance sigma2 of a noise

component, the soft decision transmitting symbol b'1 from the soft decision symbol generation section 313-1 (k) - b'N (k) are inputted into the filter factor presumption section 317-1, and make a formula (32) min in this example (k) is called for by the 2nd [an average of] power error norm of the minimum. This filter factor w1 The concrete processing which asks for (k) is described later. the adaptation filtering section 318-1 — difference — vector y'1 (k) — filter factor w1 as the identification output of an input signal [as opposed to / it is processed by (k) and / the sending signal from a user 1] — lambda 1 [b1 (k)] is outputted.

[0035] Moreover, the procedure of the multi-input multi-output turbo receiving approach of the example of this invention mentioned above is shown in drawing 3 . They are input-signal r (k) and each training signal bn at step S1. Covariance sigma2 of the channel value hmn (q) and a noise component are calculated from (k). The channel matrix H is calculated from the channel value hmn (q) at step S2. Each prior information lambda 2 acquired by the last processing in turbo reception at step S3 [bn (k)] to soft decision transmitting symbol estimate b'n (k) =tanh (lambda2 [bn (k)]/2) is calculated.

[0036] Receiving vector y (k) is generated from input-signal r (k) by step S4, and it is each soft decision transmitting symbol estimate b'n at step S5. (k) is used and it is interference replica vector B'n by formula (29) - (31). Interferent component replica H-B'n [as opposed to / generate (k) and / the input signal from the n-th transmitter at step S6] (k) is calculated. step S7 — receiving vector y (k) to interferent component replica H-B'n (k) — deducting — difference — vector y'n It asks for (k). Multiplier wn of a filter for the channel matrix H, and the soft decision transmitting symbol b'1 (k) - b'N (k) and covariance sigma2 of a noise component to remove the residual interference in the input signal from the n-th transmitter at step S8 It asks for (k) by the 2nd [an average of] power error norm of the minimum which makes a formula (32) min.

[0037] step S9 — difference — vector y'n (k) — receiving — filter factor wn filtering by (k) — carrying out — a logarithm — likelihood ratio lambda 1 [bn (k)] is obtained. step S — 10lambda1 [bn (k)] to prior information lambda 2 the day interleave after subtracting [bn (k)] — giving — further — decode — carrying out — a logarithm — likelihood ratio lambda 2 [bn (k)] is outputted. These step S4-S10 are processed being simultaneous or one by one about n= 1 - N. then — if it investigates whether the count of decode of turbo reception, i.e., a count, turned into a predetermined number at step S11 and does not have a predetermined number — step S12 — a logarithm — likelihood ratio lambda 2 [bn (k)] to external information lambda 1 [bn (k)] — subtracting — the result — an interleave — carrying out — prior information lambda 2 In quest of [bn (k)], it returns to step S3. When decode is a count of predetermined at step S11, the decode result at that time is outputted at step S13.

[0038] Next, the channel presumption section 28 is described. Each input signal rm (k) can be expressed with a degree type.

rm (k) =sigmaq=0 Q-1 sigman=1 N hmn(q) and bn+(k-q) vm (k) (33)

The channel presumption section 28 is the value and Noise vm of hmn (q) of a channel value (transmission-line impulse response) in a formula (33). It asks for the mean power (**sigma2) of (k). Usually, a transmitting side inserts unique WORD (training signal) known with a receiver at the beginning of each transmitting frame, as shown in drawing 4 A, and the receiver presumes the channel value hmn (q) using RLS (recursive least square method) etc. by making the unique WORD (known signal) into a training sequence. the logarithm from each channel decoder 24-1, --, 24-N — likelihood ratio lambda 2 [b1 (i)], —, lambda 2 About each of [bN (i)] If it is forward and negative about +1, -1, respectively Decode code-signal (transmitting coding symbol hard decision value) b1^ (i), It outputs as — and bN^ (i) and these b1^ (i), —, bN^ (i) are repeatedly inputted into the channel presumption machine 28 through INTARIBA 27-1, —, 27-N. While input-signal r (k) is inputted into the channel presumption machine 28, unique WORD is inputted as a reference sign from the unique WORD storage section 29. The channel presumption machine 28 presumes each hmn (q) of a formula (33), and each value of sigma2 with the least square method based on the these-inputted signal. This presumption can be performed by the same technique as presumption of the impulse response in the case of presuming the impulse response of a transmission line and equalizing an input signal accommodative with an adaptation

filter.

[0039] Thus, although the technique usually used uses a training sequence, it is necessary to make small the rate that the unique WORD in one frame occupies to gather a net transmission speed then, and the error of channel presumption increases. And the property of the repeat identification of the above [the error] will be degraded. Then, it is good to perform repeat presumption of a channel value as follows. The concept is shown in drawing 4 B. This also intends to presume the channel value repeatedly in each phase of repeat identification processing of the same input signal, i.e., repeat processing of turbo reception, and there is. That is, although a channel value is presumed to the information symbol sequence after unique WORD in the 1st time, using only unique WORD as a reference sign, an input signal is equalized using the presumed channel value and a transmitting symbol is presumed The symbol estimate (hard decision value) which used the unique WORD as a reference sign, performed channel presumption and was obtained by the last decode processing before identification processing of the 2nd henceforth is also used as a reference sign, and performs channel presumption within [whole] a frame. In this case, it is good to use only the hard decision value judged to be probable as a reference sign not using all hard decision values. a hard decision — the logarithm from decoder 24-n — likelihood ratio lambda 2 If this is forward using [bn (i)] and it is +1 and negative, it is carried out by being referred to as -1. that time — the logarithm — likelihood ratio lambda 2 It can be said that the hard decision value is probable, so that the absolute value of [bn (i)] is large. for example, a logarithm — 1 when judging likelihood 0.3 to be 1 — a logarithm — 1 when judging likelihood 5 to be 1 is more nearly probable. Then, a threshold is used for below and it is the probable hard decision value bn. (i) is selected and how to perform channel presumption repeatedly using it is explained.

[0040] first — the logarithm from decoder 24-n — likelihood ratio lambda 2 [bn (i)] — using — soft decision value b'n of a symbol (i) — b'n [(i) =tan h[-- lambda 2 — bn (i)]/2]

It asks by carrying out. this actuation — a logarithm — it is to standardize a likelihood value to 1 and for an absolute value not to exceed 1. Next, the threshold (between 0 and 1) is prepared beforehand and it is the soft decision value b'n. It is the hard decision value b^n to what has the larger absolute value of (i) than the threshold. (i) is saved, and this is repeated and it uses for channel presumption. For example, when a threshold is set as 0.9, it is soft decision value b'n. Absolute values are 0.9 or more hard decision value b^n among (i). (i) is sorted out. Hard decision value b^n sorted out since the threshold was as high as 0.9 Since it is thought that the probability of (i) is high, it is thought that the precision of repeat channel presumption performed using these goes up, but in order that the part and the number of symbols sorted out may decrease, it is thought that repeat channel presumption precision falls. That is, it is necessary to select the optimal threshold between 0 and 1. Hard decision value b^n sorted out when a threshold is temporarily set up with 1 as a supplement Since there is (no i), it will be said that channel presumption is not performed repeatedly. Then, although stated later, a threshold is set about to 0.2 to 0.8, and is performed.

[0041] Therefore, transmitting symbol estimate (hard decision value) b1^ to the 1st information symbol sequence (i), -- and the symbol value judged to be probable with the threshold in bN^ (i) are memorized in the symbol storage section 32 last time as transmitting symbol estimate from the output of INTARIBA 27-1, --, 27-N. In the 2nd repeat identification decode processing of input-signal r (k) (input-signal r (k) is memorized in the storage section), perform channel presumption using unique WORD first, and an information symbol sequence is received further. The last symbol storage section 32 to presumed transmitting symbol hard decision estimate b^1 (i), --, b^N Read the symbol value judged that is probable in (i), and it inputs into the channel presumption machine 28. Channel presumption is performed, that is, channel presumption within [whole] a frame is performed, and it is the estimate hmn (q) and sigma2. It uses and the identification and the decode (transmitting symbol presumption) to input-signal r (k) are performed. Under the present circumstances, the contents of storage of the symbol storage section 32 are updated last time by the symbol value was alike and judged that is probable with the threshold in that presumed transmitting symbol. Channel presumption in the case of identification and the repeat of decode performs channel presumption within [whole] a frame

like the following by presumption which uses unique WORD, and presumption using that judged that is probable in the last presumed transmitting symbol. Identification and decode (transmitting symbol presumption) are performed using the presumed channel, and the symbol storage section 32 is updated last time. In addition, in the symbol storage section 32, it is the transmitting symbol hard decision value b^1 from a decoder last time [this]. (i), —, b^N Renewal of direct storing of the symbol value judged that is probable with the threshold in (i) is carried out last time at the symbol storage section 32, and when using the storage symbol value of the symbol storage section 32 last time [this], you may make it input into the channel presumption machine 28 through INTARIBA 27-1, —, 27-N.

[0042] By doing in this way, by the repeat, the error of channel presumption can decrease, the precision of symbol presumption can improve, and the problem of property degradation by the channel presumption error in turbo identification can be solved. Thus, when performing channel presumption in an information symbol sequence using a probable symbol hard decision value, the functional configuration shown in drawing 5 is added to each decoder 24-n. a logarithm — likelihood ratio lambda 2 [bn (i)] is inputted into the soft decision value presumption section 241. b'n(i) =tanh (lambda2 [bn (i)]) is calculated, and it is transmitting symbol soft decision value b'n. (i) is presumed. This value b'n (i) is compared with threshold Th from the threshold setting section 243 by the comparator 242, and it is b'n. 0 is outputted for (i) by smallness from 1 and Th above Th. on the other hand — a logarithm — likelihood ratio lambda 2 [bn (i)] is inputted into the hard decision section 244. lambda 2 Symbol hard decision value b^n set to -1 if [bn (i)] was forward and it was +1 and negative (i) is outputted and it is this symbol hard decision value b^n. (i) With [a corresponding symbol soft decision value] a threshold [more than], it is outputted, the gate 245 being used as open, the symbol storage section 32 is supplied last time through INTARIBA 27-n in drawing 1 , and said symbol under storage is updated.

[0043] Moreover, the procedure of channel presumption also using a probable symbol hard decision value comes to be shown in drawing 6 . Channel presumption by input-signal r (k) and unique WORD is first performed at step S1, decode processing investigates whether it is the 1st time at step S2, and if it is the 1st time, steps S3-S10 under identification and decode processing, i.e., drawing 3 , will be processed using the presumed channel value hmn (q) at step S3. step S4 — a logarithm — likelihood ratio lambda 2 [bn (i)] — receiving — transmitting symbol hard decision processing — carrying out — hard decision value b^n (i) — asking — step S5 — a logarithm — likelihood ratio lambda 2 [bn (i)] — receiving — b'n (i) =tanh (lambda2 [bn (i)]/2) — calculating — transmitting symbol soft decision value b'n (i) is presumed. It is symbol soft decision value b'n at step S6. (i) is correspondence symbol hard decision value b^n by whether it is more than threshold Th. The probable thing of (i) is determined and the contents of storage in the symbol storage section 32 are updated last time with the probable symbol hard decision value at step S7. Next, if it investigates whether the count of decode is a predetermined value at step S8 and has not become a predetermined value, it returns to step S1. It returns to step S1 in drawing 3 through step S12 in drawing 3 correctly.

[0044] If judged with decode processing not being 1 time at step S2, it will read from the symbol storage section 32 last time by step S9, the last storage symbol, i.e., probable hard decision symbol, channel presumption will be performed using this and the information symbol sequence of input-signal r (k), and it will move to step S3. In the above, also in processing of the 2nd henceforth, unique WORD carried out channel presumption from the initial state as a reference sign, and 2nd henceforth may use only the hard decision symbol appropriate for ** as a reference sign. In this case, it investigates whether it is the 1st processing by step S1', and if it is the 1st processing, a channel value is presumed for unique WORD by this and the input signal as a reference sign by step S2', and as a broken line shows in drawing 6 , after memorizing that presumed channel value and the value of each parameter used for that presumption in the storage section by step S3', it will move to the identification of step S3, and decode processing.

[0045] If it is not the 1st time in step S1', in advance of channel presumption processing, the channel estimate and the various processing parameters which were previously memorized by step S4' will be set up, and it will move to step S9. The solution (32) to serves as a degree type in a place.

wn (k) =(HG(k) HH+sigma2 I)-1 and h (34)
I is a unit matrix and sigma2. It is the internal-noise power (covariance of a noise component) of a receiver, and sigma2 I corresponds to the covariance matrix of a noise component, and G (k) corresponds to a channel presumption square error.
[0046]
G (k) **E [(B (k)-B' (k)) -(B (k)-B' (k)) H]
= diag [D (k+Q -1), --, D (k), --, D (k-Q +1)]
(35)
E[] expresses an average and diag expresses a diagonal matrix (elements other than the element of the diagonal line are zero). Again D(k+q) =diag [1-b'21 (k+q), --, 1-b'2 n (k+b), --, 1-b'2 N] (k+q) (36)
At the time of q=Q -1, Q-2, --, -Q+1, and q!=0q=0 D(k) =diag [1-b'21 (k), --, 1, --, 1-b' 2 N (k)] (37)
One in Vector D (k) is the n-th element (it is considering as the signal of a request of the n-th user's sending signal).
[0047]
[Equation 19]

$$h=\begin{bmatrix} H_{1,(Q-1)\cdot N+n} \\ H_{2,(Q-1)\cdot N+n} \\ \vdots \\ H_{M\cdot Q,(Q-1)\cdot N+n} \end{bmatrix} \qquad (38)$$

[0048] That is, h consists of all elements of eye a -(Q-1) N+n train of H of a formula (23). The channel matrix H presumed with the channel presumption vessel 28 in the filter coefficient presumption section 317-1 of the multi-output equalizer 31 as shown in drawing 2 , and noise power sigma2 Soft decision transmitting symbol b'1 from the soft decision symbol generation section 313-1 (k) - b'N (k) is inputted and the residual interference removal filter factor wn (k) calculates by formula (34) - (38). Although an inverse-matrix operation will be performed, as for a formula (34), this operation can reduce the amount of operations by using the lemma (Matrix Inversion Lemma) of an inverse matrix. That is, a formula (36) and b'each 2 of (37) When all parts are approximated to 1, it is D(k+q) =diag[0, --, 0] =0. (q!=0) (39)
D(k) =diag (0, --, [1, --, 0]) (40)
That is, as for all other elements, only the element of the n line n train in the element of D (k) is set to 0 by 1. It is wn if error matrix [of the formula (35) decided by these formulas (39) and (40)] G (k) is substituted for a formula (34). (k) =(h-hH+sigma2 I)-1 and h (41)
It becomes. h was defined by the formula (38).
[0049] By this approximation, it is wn. In order that (k) may not be dependent on k, it becomes unnecessary inverse-matrix calculating [of every discrete time of day k], and computational complexity is reduced. The lemma of an inverse matrix is applied to this formula (41). The lemma of this inverse matrix makes the square matrix of (M, M), and C as a matrix (M, N), and makes D the square matrix of (N, N) for A and B, and it is A=B-1+CD-1 CH. When expressed, it is the inverse matrix of A. (42) A-1=B-BC(D+CH BBC)-1CH B
It is come out and given. It is set to -1+CD-1CHh(k) -h(k) H =CD-1 CH, sigma2 I=B -1, h(k) =CI=D -1, and h(k) H =CH. if this theorem is applied to the part of the inverse-matrix operation in a formula (41) -- h(k) -h(k) H+sigma2 I=B -- If a formula (42) is calculated using this, the inverse-matrix operation in a formula (41) can be found. In addition, although the inverse-matrix operation (D+CH BBC) -1 is included also in a formula (42), since this inverse matrix serves as Scala, it is easily calculable.
[0050] That is, it is wn in this case. (k) =1/(sigma2+hH and h) h (41-1) It becomes. 1/( ) of the right-hand side of this formula is good also as 1, scalar, i.e., since it becomes in fixed numbers. Therefore, wn Since it can place with (k) =h, it is w only at h. (k) is determined. What is necessary is to input into the filter coefficient presumption section 317-1 in drawing 2 only h shown by the formula under channel matrix H (38) from the channel presumption machine 28, as

a broken line shows.
[0051] In addition, the approximation by the formula (39) and the formula (40) can lessen computational complexity of a formula (34) not only when using the lemma of an inverse matrix, but by this approximation. If especially this approximation is performed, and the lemma of an inverse matrix is used, the amount of operations can be decreased further and the covariance matrix of a noise component will be set to sigma2 I in that case, it is wn as shown in a formula (41-1). It can approximate by (k) =h, and becomes unrelated to a covariance matrix, and count is simplified further.
Signal bn detected in the identification processing which subtracts H-B' (k) from receiving vector y (k) shown in the 2nd invention (error correction reflection) type (27) The transmitting symbol soft decision value of signals other than (k) is the signal bn detected although the error correction decode result is reflected. The error correction decode result about (k) is not reflected. Then, processing as follows is desirable.
[0052] It changes into a degree type, b' (k) (31), i.e., the formula, in a formula (29).
b — ' — (— k —) — = — [— b — ' — one — (— k —) — — b — ' — two — (— k —) — — b'n - one — (— k —) — — f (b'n (k)) — — b'n — + — one — (— k —) — b'N — (k) —] — (43)
however, f (b'n (k)) — b'n the function of the arbitration which considers (k) as an input — signal bn detected by doing in this way It becomes possible to make an error correction decode result reflect also about (k). That is, it is without it is referred to as b'n (k) =0 (the signal which carries out **** leak ****** will be emphasized to a noise or an interference signal, and bn (k) can be correctly detected by adding the suitable value according to b'n (k).).
[0053] About f (b'n (k)), it is b'n. The sign of (k) is b'n. It is related to the hard decision result of the symbol corresponding to (k), and b'n. It is b'n, so that the absolute value of (k) is large. It is necessary to fulfill the following conditions from the property in which the dependability of the hard decision symbol corresponding to (k) is large. b'n When the dependability of (k) =0, i.e., a hard decision symbol, is 0, the value of this function f is also 0. namely, — f(0) =0 (44)
It comes out. Moreover, b'n If the value of (k) is large, the value of Function f will also turn into a big value. namely, — d{f(b'n (k))}/d{b'n (k)} >=0 (45)
It comes out. As the example of such f (b'n (k)) f(b'n (k)) = alphaxb'n (k) (46)
f(b'n (k)) = alphaxb'n 2 (47)
*************. For example, a constant, then a formula (43) are [alpha] easily realizable using a formula (46). alpha is 0< alpha<0.6 here. If alpha is made larger than 0.6, a BER (error rate) property will deteriorate conversely and a right decode result will no longer be obtained. Moreover, carrying out adjustable [of the alpha] according to the reliability of a decode result is also considered. For example, alpha is set up for every repeat of decode processing. In this case, what is necessary is just to enlarge the value of alpha according to the count of a repeat of decode processing, in order that the reliability of a decode result may go up so that the count of a repeat of decode processing usually increases. Or what is necessary is to judge the reliability of the whole frame decoded for every repetition of decode processing, and just to determine the value of alpha based on the judgment. How to count the number of hard decision symbols which changed for example, the decode result from the time of the last decode as an approach of judging the reliability of the decoded frame, as compared with the decode result at the time of repeat decode 1 time ago can be considered. Namely, what is necessary is to judge with reliability being low, when there are many hard decision symbols which changed, and just to judge with reliability being high, when there are few hard decision symbols which changed.
[0054] Moreover, such b'n It follows on modification of (k) and is the multiplier wn of an MMSE (2nd [an average of] power error of the minimum) filter. It is desirable to change as follows the formula (35) used in case it asks for (k).
G (k) =E[(B(k)-B' (k)) - (B(k)-B' (k))
)H]
= diag [D (k+Q -1), —, D (k), —, D (k-Q +1)]
It is [0055] from a formula (29) and a formula (31) here.
[Equation 20]

$$B'(k)=\begin{bmatrix} b'(k+Q-1) \\ b'(k+Q-2) \\ \vdots \\ b'(k) \\ \vdots \\ b'(k-Q+1) \end{bmatrix} \qquad b'(k)=\begin{bmatrix} b'_1(k) \\ b'_2(k) \\ \vdots \\ -f(b'_n(k)) \\ \vdots \\ b'_N(k) \end{bmatrix}$$

[0056] It carries out. The element of the n line n train of D (k) is E [[(bn (k)+f (b'n (k)))] and [and] (bn (k)+f (b'n (k)))] *[ ]*. A complex conjugate is expressed. In a BPSK modulation, this formula turns into a degree type.
E — [— bn — (— k —) — two — + — 2b — n — (— k —) — f (b'n (k)) — + — f (b'n (k)) — two —] — = — E — [— bn — two — (— k —) —] — + — two — E — [— bn (k) f (b'n (k)]+E [f (b'n(k)2]))
The average of this 1st term is set to 1. Moreover, bn A formula (37) is as follows when (k) is approximated by b' (k).
[0057]
D (k) — =diag[1-b'21(k) 1- b'22(k) — 1-b'2n- 1 (k) — 1+2E[f (b'n (k) b'n (k))]+E[— f (b'n (k)2] — 1-b'2n+1 (k) — 1-b'21 (k) —])
(48)
For example, D (k) is as follows when f (b'n (k)) is made into a formula (46).
D — (— k —) — = — diag — [— one - b — ' — 21 — (— k —) — — one - b — ' — 22 — (- - k —) — — one - b — ' — two — n - one — (— k —) — — one — + (2 alpha+alpha 2) — b — ' — two — n — — (— k —) — — one - b — ' — two — n — + — one — (— k —) — 1- b'21 (k) —] — (49)
Thus, when making an error correction decode result reflect in the signal to detect, it is the adaptation filter factor wn. It is the sending signal b1 from the 1st transmitter as a signal which detects the example of a functional configuration which presumes (k). The case where it is referred to as (k) is shown in drawing 7 A. Soft decision transmitting symbol b'1 (k) is inputted into the function operation part 331-1, and the function operation f (b'1 (k)) calculates. Moreover, soft decision transmitting symbol b'1 from the decoder of N individual (k) - b'N (k), and f (b'1 (k)) are inputted into the error matrix generation section 332-1, and operation generation of the error matrix G (k) is carried out by a formula (35), a formula (36), and the formula (48). This error matrix G (k), and the presumed channel matrix H and noise power sigma2 It is inputted into the filter factor generation section 333-1, a formula (34) is calculated here, and it is the adaptation filter factor wn. (k) is presumed. In this case, f (b'n (k)) is inputted also into the interference replica vector generation section 314-1, and interference replica vector B[of a formula (30) and a formula (43) to a formula (29)] ' (k) is generated. filter coefficient wn (k) — difference — vector y' (k) carries out filtering in the adaptation filter section 318-1 — having — a logarithm — likelihood ratio lambda 1 [b1 (k)] is obtained. In addition, in the case of the filter factor presumption section 317-1 in drawing 2 , the function operation part 331-1 in drawing 7 A is omitted, and it is the soft decision transmitting symbol b'1. (k) - b'N (k) will be inputted into the error matrix generation section 332-1, and a formula (34) will calculate.
[0058] Although interference replica vector B' (k) is generated by step S4 in drawing 3 , steps S5-S7 are processed further and it asks for the filter factor wn in step S8 (k) When calculating a formula (34) in processing of this step S8 As shown in drawing 7 B, it is the soft decision transmitting symbol b'1 at step S8-2. (k) - b'N (k) is used. Formula (35) - (37) is calculated, error matrix G (k) is generated, and it is error matrix G (k), the presumed channel matrix H, and noise power sigma2 at step S8-3. It uses and is the adaptation filter factor wn by the operation of a formula (34). It asks for (k).
[0059] To reflect an error correction decode result in the signal detected as mentioned above Soft decision transmitting symbol b'n of a signal to detect by step S8-1 before step S4 in

drawing 7 B The function operation of the (k) is carried out. What is necessary is to use a formula (43) instead of a formula (31), that is, for a formula (29), a formula (30), and a formula (43) to generate interference replica vector B' (k), and just to use a formula (48) instead of a formula (37) by step S4, step S8-2 using this. As mentioned above, it is f (by the case where it considers as alphab'n (k) or alphab'n (k) 2, b'n (k)). When changing alpha, the reliability of the count of processing or the decoded whole frame determines alpha by step S8-1-1, and it is 1+(2 alpha+alpha 2) b'n at step S8-1-2. 2 What is necessary is to calculate and just to use as f (b'n (k)).

[0060] The technique of making an error correction result reflect in this signal to detect is applicable also to the single user turbo receiver explained by the term of the conventional technique. Moreover, what is necessary is to be able to apply the approximation shown in a formula (39) and (40), and just to input into the filter coefficient generation section 333-1 the matrix h shown in a formula (38) from the channel presumption machine 28 in this case, in the technique of making an error correction result reflect in this signal to detect, as a broken line shows in drawing 7 A. By ****, it is the adaptation filter coefficient wn. Although it asked for (k) by the formula (34), that is, being asked using the channel matrix H, it is not necessary to use the channel matrix H. That is, in the 1st time of decode processing (turbo reception), the error vector G in a formula (34) serves as a unit matrix. therefore, difference — vector y' (k), a training signal or this, and hard decision transmitting symbol b^n (k) — it mentioned above preferably — as — b^n with high reliability (k) — the filter factor generation section 333-1 — inputting — RLS (recursive least square method) etc. — applying — serially — a target — adaptation filter factor wn (k) may be computed. The error vector G is the adaptation filter coefficient wn 2nd after repeat processing of decode, in order to be dependent on the discrete time of day k. It is necessary to update (k) for every symbol, as stated previously, the channel matrix H is used, and it is the adaptation filter factor wn. It is desirable to determine (k).

[0061] The 4th invention (channel presumption)

It repeats, as mentioned above. To channel presumption the hard decision value of not only known information like unique WORD but an information symbol, and also using especially the probable thing as a reference sign Not only in when using for said multi-input multi-output turbo receiving approach, generally Presume the channel (transmission line) of an input signal from an input signal and a known signal, decode by processing an input signal using the presumed channel value, and the decode signal is used. It is applicable to the turbo receiving approach of performing the processing and decode processing by the channel value which repeated and presumed the same input signal.

[0062] The example which also applied the hard decision value of this information symbol to channel presumption and the turbo equalizer 41 at drawing 8 is shown. The turbo equalizer 41 determines a linear equalization filter factor with a presumed channel value, processes an input signal with the linear equalization filter, decodes the processed signal, and repeats and processes the same input signal using the decode signal. Input-signal r (k) is supplied to the channel presumption machine 42 while it is inputted into the turbo equalizer 41. With the channel presumption vessel 42, a channel value (line characteristic) is presumed by input-signal r (k) and the unique WORD from the storage section 29. Identification processing of the input-signal r (k) is carried out by the presumed channel value within the turbo equalizer 41, and after that, while decode processing is carried out and decode data c' (i) is outputted, soft decision value b' (i) is outputted. By being inputted into the symbol selection machine 43, if the absolute value of soft decision value b' (i) is more than threshold Th, soft decision value b' (i) Updating storing of the hard decision value b^ (i) is carried out last time as a probable (reliable) thing at the symbol storage section 32. In the channel presumption processing in the channel presumption section 42 at the time of repeating and carrying out reception (equalizing processing) of the future same input-signal r (k), not only unique WORD but hard decision value b[of the information symbol memorized by the symbol storage section 32 last time]^ (i) is used.

[0063] The turbo equalizer 41 is a part except the symbol storage section 32 the repeat channel presumption machine 28 receiving in a plane shown in drawing 1 , the unique WORD storage section 29, and last time. You may be a receiver in drawing 29 . That is, the solution (19) to

serves as the following by the Wiener solution also in this case.
w(k) =E[y'(k) y'H (k)] and E[b (k) -y' (k)
]
= [Hlambda(k) H+sigma 2 I] -h (50)
It is the thing and sigma2 =E [||v||2] (distribution of a noise) as which H was defined by the formula (8) here, and h**[H (Q-1), --, H (0)] TH( ) was defined by the formula (5).
lambda(k) =diag[-- 1-b' -- 12 (k+Q -1), --, 1, --,-b'2] (k-Q +1)
Thus, also in the receiver in drawing 29 , presume channel H ( ), it identification filter-factor w (k) Asks using this channel H ( ), filtering of the input signal is carried out by filter factor w (k), and decode processing is performed to that processed output. Therefore, in this repeat reception, right channel presumption can be obtained more by using a hard decision information symbol with said dependability for channel presumption.
[0064] Drawing 9 shows the example of the turbo receiver which applied said repeat channel presumption approach to the repeat reception which performs lake (RAKE) composition processing. Input-signal r (k) is supplied to the RAKE composition processing section 45 and the channel presumption machine 42. A channel value is presumed by input-signal r (k) and unique WORD with the channel presumption vessel 42, and compensation over the phase rotation which each symbol received in the RAKE composition processing section 45 in the transmission line, and RAKE composition processing are performed by the presumed channel value, that is, time diversity processing is performed, and the 1st time is outputted to the turbo decoder 46. Decode data c' (i) and soft decision value b' (i) are outputted from the turbo decoder 46. Soft decision value b' (i) is inputted into the symbol selection machine 43, and like said example, although seemingly it is the **, updating storing of hard decision value b[of an information symbol]^ (i) is carried out last time at the symbol storage section 32. In the repeat reception of RAKE receiving-turbo decoding of the 2nd henceforth, not only unique WORD but the hard decision value of the last information symbol is used for channel presumption with the channel presumption vessel 42. Thereby, since presumption of a channel can carry out to accuracy more, improvement in quality can be aimed at.
[0065] Drawing 10 shows the example of the turbo receiver which used the adaptive (adaptation) array antenna and which applied said repeat channel presumption approach to reception repeatedly. Input-signal r (k) is received by the adaptive array antenna receive section 47. The branching input of the input signal is carried out at the channel presumption machine 42, and channel presumption is performed by this and unique WORD. Using the presumed channel value, toward the arrival direction of the purpose wave, the main beam of the antenna directional characteristics of the adaptive array antenna receive section 47 so that null may be suitable in the arrival direction of an interference wave The weight to each antenna element or a corresponding receiving path is determined in the array weight decision section 48, and the weight is set as an applicable part. The reception output of the adaptive array antenna receive section 47 is supplied to the turbo decoder 46, and is decoded, the decode data c' (i) and soft decision value b' (i) are outputted, soft decision value b' (i) is inputted into the symbol selection machine 43, and the updating storage of the probable hard decision value is carried out last time at the symbol storage section 32. In the repeat reception of the adaptive array antenna receive section 47-turbo decoder 46 of the 2nd henceforth, not only unique WORD but the hard decision value of the last information symbol is used for channel presumption with the channel presumption vessel 42. Channel presumption is performed more correctly by this, consequently control of antenna directional characteristics is performed more to accuracy, and improvement in quality can be aimed at.
[0066] In addition, if the turbo equalizer 41 in drawing 8 is shown simple, as shown in drawing 11 A, it will be the format of the series connection of ************ (SISO) equalizer (equalizer) 41a and SISO decoder (decoder) 41b, and repeat actuation will be performed between these equalizer 41a and decoder 41b. If the turbo decoder 46 in drawing 9 and drawing 10 is shown simple, as shown in drawing 11 B, it will be the format of the series connection of SISO decoder 46a and SISO decoder 46b, and decode will be repeatedly performed between decoder 46a and 46b. Even for a SISO decoder, drawing 9 R> 9 and the turbo decoder 46 in drawing 10 are.

[0067] The example shown in the above drawing 8 thru/or drawing 10 is collectively shown in drawing 12 . That is, it processes with the channel value which repeated the input signal and was first presumed with the channel presumption vessel 42 with the receiver (turbo receiver) 49. Carry out decode processing of the processed signal, output decode data (symbol) c' (i) and its soft decision value b' (i) as the decode processing result, and the soft decision value b' (i) is set in the symbol selection vessel 43. As compared with a threshold, that judged whether correspondence decode data c' (i) and a (symbol hard decision value) would be probable, and judged that is probable carries out updating storing of the hard decision value last time at the symbol storage section 32. It is made to perform channel presumption besides known information like unique WORD at accuracy to channel presumption in the channel presumption machine 42 in the repeat of processing-decode processing using the presumed channel value of the 2nd henceforth more also using the last symbol hard decision value.
[0068] The example of the procedure of the repeat input-signal approach of also using this symbol hard decision value for drawing 13 is shown. A channel value will be presumed with an input signal and a known signal at step S1, and it will investigate whether it is the 1st time of repeat processing at step S2, and if it is the 1st time, an input signal is processed with the channel value presumed at step S1 by step S3, after that, decode processing will be performed and a symbol hard decision value and a soft decision value will be calculated. The last symbol hard decision which memorizes to drawing by step S4 and has memorized what has the symbol soft decision value to a probable correspondence symbol hard decision value in the storage section 32 at step S5 at the taken-out symbol hard decision value is updated. Decode processing investigates whether it is a count of predetermined at step S6, and if it is not a count of predetermined, it returns to step S1. If it is not the 1st time of repeat processing at step S2, the last symbol hard decision value will be read from the storage section 32 at step S7, this and the information symbol of an input signal will perform channel presumption, and it will move to step S3.
[0069] As step S1' - S4' explained with reference to drawing 6 also in this case, processing of the 2nd henceforth does not need to use a known signal. Between the adaptive array antenna receive section 47 and the turbo decoder 46, as a broken line shows the example shown in drawing 10 , the RAKE composition processing section 45 may be inserted. In this case, channel presumption for each symbol phase spin compensation in the RAKE composition processing section 45 and RAKE composition may be made to serve a double purpose with the channel presumption vessel 42, and may be prepared according to an individual.
[0070] It processed in the example of the 2nd invention in consideration of the example and error correction of the turbo receiving approach (the 1st invention) which carried out the noise above-mentioned other than the white nature Gaussian random noise, and the example of the turbo receiving approach (the 4th invention) of having the description in the channel presumption approach, having assumed that a noise was white nature Gaussian random noise. Namely, input signal rm of each antenna vm in the right-hand side of the formula (20) showing (k) (k) is assumed in case of white nature Gaussian noise. White nature Gaussian noise follows Gaussian distribution, and is E[vm (k) and vm] (k-q) =sigma2 here. : In the case of q= 0, in the case of 0:q! =0, E[] is expected value and sigma2. It is a variance. It is the signal which has the becoming statistical property. The thermal noise which generates white nature Gaussian noise within an antenna element is mentioned as an example. It is a filter factor wn that the assumption of this white nature Gaussian noise is reflected. It is the part of sigma2 I in the formula (50) which asks for the formula (34) which asks for (k), or filter factor w (k). For example, wn of a formula (34) (k) and wn (k) =(HG(k) HH+E [n(k) and nH (k)])-1h = (HG(k) HH+sigma2 I) it is computed through a -1h process. Here, it is vm. (k) is distributed sigma2. It is calculated with n(k) and E[nH (k)] =sigma2 I by assumption called the white nature Gaussian noise which it has. channel matrices H and sigma2 presumed by the repeat channel presumption machine 28 (drawing 1) or 42 (drawing 1212) beforehand -- a logarithm -- error matrix G (k) calculated from a likelihood value -- a formula (34) -- substituting -- filter factor wn (k) is computed.
[0071] In a place, it is Noise vm. The case where (k) is not white nature Gaussian noise is considered. In this case, since it cannot be referred to as n(k) and E[nH (k)] =sigma2 I, it is a

filter factor wn. In order to compute (k), it is necessary to presume expected-value (covariance) matrix [of a noise component] E [n(k) and nH (k)] by the option. This approach is explained below. The covariance matrix of a noise component is written as U**E [n(k) and nH (k)] here. It will become a degree type, if y(k) =H-B(k)+n (k) of a formula (22) is transformed with n(k) =y(k)-H-B (k) and it substitutes for a covariance matrix U.
[0072]
U=E [n(k) and nH (k)]
= E [(y(k)-H-B (k)) -(y(k)-H-B (k)) H]
Now, if B (k) is [input signal] available by estimate H^ of the channel matrix H, and the reference sign in vector y (k) and channel estimate, Matrix U is a time average method.
U^=sigmak=0 Tr (y(k)-H^-B (k)) and (y(k)-H^-B (k)) H (51) It can presume. Here, Tr is the number of reference-sign symbols.
[0073] Covariance-matrix U^ is presumed with the channel matrix H using a formula (51) during the repeat channel presumption machine 28 or repeat channel presumption in 42. The procedure is shown in drawing 14 . The unique WORD and the information symbol sequence in one frame in an input signal are shown in drawing 14 A, and processing of the 1st henceforth is shown in drawing 14 B. The 1st processing makes only unique WORD a reference sign, and presumes the channel matrix H first. Next, U is presumed to be unique WORD by the formula (51) using the channel matrix estimate H^. These estimate U and H^ are used and it is a filter factor wn (k).
wn (k)=(H^G(k)H^H +U^)-1h (52)
It computes and is this filter coefficient wn. 1st identification to an input signal is performed using (k), and a transmit information symbol is presumed.
[0074] Among the information symbols presumed to be unique WORD by the 1st identification, the 2nd processing re-presumes U, after re-presuming H in the same procedure as the 1st time by making into a reference sign both thing * judged that is probable with the threshold. By repeating this actuation, for every repeat, channel matrix estimate H^ becomes more exact, and the estimate of U becomes more exact, and it is a filter factor wn. The precision of (k) goes up and the property of an equalizer improves. Turbo reception in case the noise which is not white nature Gaussian random noise is included in an input signal by the above processing can be performed.
[0075] as the identification output of the input signal of the sending signal from the 1st transmitter of the multi-output equalizer 31 which showed the functional configuration in the case of presuming the covariance matrix U of the noise in the input signal mentioned above, and performing linear equalization processing in drawing 2 -- a logarithm -- likelihood ratio lambda 1 The example applied when asking for [b1 (k)] is shown in drawing 15 . The same reference number is attached to drawing 2 in drawing 15 , and a corresponding part. Last time, the unique WORD from the unique WORD storage section 29 or the last symbol hard decision probable from the symbol storage section 32 is inputted into the reference vector generation section 319, and reference vector B (k) is generated by a formula (25) and the formula (26) here. This reference vector B (k), presumed channel matrix H^ from the channel presumption machine 28, and receiving vector [from the receiving vector generation section 311] y (k) are supplied to the covariance-matrix presumption section 321, a formula (51) is calculated here, and presumed matrix U^ of a covariance matrix U is obtained.
[0076] Moreover, the soft decision transmitting symbol soft decision b'1 from the soft decision symbol generation section 313-1 (k) - b'n Error matrix G1 to which (k) is inputted into the error vector generation section 322-1, and corresponds with a channel presumption square error by the formula (35), the formula (36), and the formula (37) here (k) is generated. This error matrix G1 (k), presumed covariance-matrix U^, and presumed channel matrix H^ are supplied to the filter presumption section 323-1, a formula (52) is calculated here, and it is a filter factor w1. (k) is presumed. this filter coefficient w1 the difference from (k) and the difference operation part 316-1 -- filtering [as opposed to / vector y' (k) is supplied to the adaptation filter 318-1, and / y' (k)] w1 (k) H y' (k) should do -- that result -- a logarithm -- likelihood ratio lambda 1 It is outputted as [b1 (k)].
[0077] When making an error correction decode result reflect also about the signal to detect As

a broken line shows in drawing 15 , form the function operation part 331-1 shown in drawing 7 R>7A, and f (b'n (k)) is calculated. What is necessary is to use a formula (43) instead of a formula (31) in the interference replica vector generation section 314-1, and just to use a formula (48) instead of a formula (37) in the error vector generation section 322-1. The technique shown in drawing 14 B is shown in drawing 16 as a flow chart. That is, the channel matrix H will be presumed using input-signal r (k) and a known signal (for example, unique WORD) at step S1, and next, it investigates whether this processing is the 1st time in repeat processing at step S2, and if it is the 1st time, it will calculate a formula (51) using a known signal, presumed channel matrix H^, and input-signal r (k) at step S3, and will ask for presumed covariance-matrix U^.

[0078] A formula (52) is calculated using error matrix G (k) which becomes presumed channel matrix H^ and presumed covariance-matrix U^ with a symbol soft decision value by step S4, and it is a filter factor wn. (k) is presumed. step S5 — presumed channel matrix H^ and filter factor wn (k) — using — an input signal — identification processing — carrying out — that is, a formula (27) — calculating — wn H (k) -y' (k) — calculating — a logarithm — likelihood ratio lambda 1 It asks for [bn (k)], decode processing is performed to this, and the hard decision value and soft decision value of a transmitting symbol are presumed.

[0079] Step S6 calculates the probable (it is reliable) symbol hard decision value which corresponds from the symbol soft decision value more than a threshold. With this symbol hard decision value, the symbol hard decision value stored in the symbol storage section 32 last time is updated. Then, if it has not come to investigate whether the count of decode processing became a predetermined value at step S8 and is return and a predetermined value to step S1, the processing to the receiving frame will be ended. If the processing in repeat processing is not the 1st time at step S2 (i.e., if it is 2nd henceforth), a symbol hard decision value will be read from the symbol storage section 32 last time by step S9, the channel matrix H will be presumed by this and the information symbol in an input signal, and it will move to step S3.

[0080] 2nd henceforth can be prevented from using a known signal by changing steps S1 and S2 into the same processing as step S1' shown with the broken line in drawing 6 also in this case - S4'. Moreover, what is necessary is to perform the function operation f (b'n (k)) at step S10 into drawing 16 , as a broken line shows when the signal to detect also wants to make an error correction decode result reflected, and just to ask for error matrix G (k) using this result. Furthermore, in the case of which, it is not necessary to use a hard decision transmitting symbol at presumption of covariance-matrix U^. it is said below that the covariance matrix U of that noise in the input signal in which the noise which is not this white nature Gaussian noise was included can be presumed — as — various kinds — it is applicable to useful application.

[0081] (1) The receiving method for the multi-sequence sending signal in which an interference signal with a strange receiver is included is mentioned. As shown in drawing 28 , suppose that strange interference signal i (k) (for example, signal from the cel and zone of others [mobile communication]) is received by the turbo receiver in addition to the sending signal of the sequence of N individual like the signal from the transmitter of the user of N man whom a turbo receiver tends to receive as a broken line shows. At this time, it is a formula (20). rm (k) =sigmaq=0 Q-1 sigman=1 N hmn(q) and bn+(k-q +1) i(k)+vm (k) It becomes (20) '. It sets to this model and is i(k)+vm. (k) **v'm If (k) rm (k) =sigmaq=0 Q-1 sigman=1 N hmn(q) and bn+(k-q +1) v'm (k) It becomes (20) ". v'm As a noise signal which is not white nature Gaussian noise, (k) performs presumption of H, and presumption of further U, as stated previously, and it is wn. (k) can be presumed and turbo reception can be performed by repeating identification processing of an input signal, and transmitting symbol presumption.

[0082] (2) In the communication system using a transceiver separation filter, in case over sampling technique is performed from 1/2 of a symbol period to an input signal at high speed, correlation cannot come out between the noise components contained in the input signal by which the sample was carried out by each time amount, and it cannot be considered that the noise in an input signal is white nature Gaussian noise. That is, it sets at a ceremony (20) and is E[vm (k) and vm] (k-q) =sigma2. : In the case of q= 0, it does not become the case of 0:q!=0. Therefore, the assumption E[n(k) and nH (k)] =sigma2 I Becoming cannot be performed. Then, by performing processing to the input signal separated with the transceiver separation filter in quest

of a covariance matrix U using a formula (51), an input signal can be processed correctly.
[0083] (3) By the turbo receiving approach mentioned above, all the multi-pass components of Q pass from each transmitter (user) are compounded, and it has become constructing. however, when a long delay wave exists in a channel (example: — pass — the pass component of 1 symbol delay, 2 symbol delay, and 30 symbol delay in case it is 3-symbols-delayed, and it flies and 30 symbol delay exists), it is possible to take the plan which does not compound a long delay wave, but treats it as strange interference, and is removed with an adaptation filter. That is, a long delay wave is removable by treating this long delay wave component as interference signal i (k) in the example of the above (1).
[0084] In the processing to the input signal in which the noise which is not the white nature Gaussian noise mentioned above was included Presumption of a covariance matrix U is presumed instead of sigma2 I in a formula (50). Are applicable also to the single user turbo receiving approach. Similarly A single user, Irrespective of multiuser, it is applicable to the turbo reception using the adaptive array antenna reception shown in the RAKE composition processing reception shown in drawing 9 , or drawing 10 , channel presumption with the channel [in / repeatedly / decode] presumption vessel 42 still more generally shown in drawing 12 , and presumption with a covariance matrix U. In addition, in RAKE reception, only channel presumption may be used.
[0085] the 3rd invention (multistage identification) **** — input signals r1, —, rM the multi-output equalizer 31 — it is — equalizing — a logarithm — likelihood ratio lambda 1 [b (k)], —, lambdaN Although it asked for [b (k)], in the modification (2) of the 1st invention, two or more identification stages are prepared in concatenation, and a more nearly latter equalizer is good also as a configuration which lessens the number of outputs. For example, as shown in drawing 17 , by dividing into two for this, with the preceding paragraph equalizer (multiuser equalizer) 71, the interferent component outside the identification range of latter single user equalizer 21' is canceled, therefore pretreatment of software interference cancellation and MMSE (2nd [an average of] power error of the minimum) norm linearity filtering is performed, for example, and the numbers of passes shown previously perform identification processing of the single user of Q by latter-part equalizer 21' after that.
[0086] Thus, identification processing is carried out in concatenation and computational complexity can be prevented from becoming immense also by using a linearity filter for processing of the preceding paragraph. The example of the MIMO structure of a system to which the configuration and this invention of the example based on the underlying concept of the 1st invention (2) of this turbo receiving method of a multi-output turbo receiver are applied is shown in drawing 18 , the same reference number is attached to drawing 1 and a corresponding part, and duplication explanation is omitted (the same is said of the following explanation). The sending signal from each transmitter is received through a transmission line (channel) by the turbo receiver 30. This input-signal r (k) is inputted into the multiuser equalizer 71. From this equalizer 71 Signal u1 with which interference by the signal from the transmitter of others [signal / from each transmitter of N individual] was removed, respectively (k), — and uN (k) and each channel value alpha 1 (k), —, alphaN (k) is outputted and it is inputted into the single user equalizer 21-1, —, 21-N, respectively. from these SISO(s) equalizer 21-1, —, 21-N — respectively — a logarithm — likelihood ratio lambda 1 [b1 (k)], —, lambda 1 [bN (k)] is outputted. Although future processings are the same as that of the case of drawing 1 R> 1 than this, they are the single user equalizer 21-1, —, the channel value alpha 1 used by 21-N. (k), —, alphaN (k) is a channel value after multiuser identification, and differs from the channel matrix H. Therefore, this alpha 1 (k), —, alphaN (k) is described as the channel information after identification.
[0087] Hereafter, actuation of each part is explained. In consideration of several Q of a multi-pass (channel), formula (23) - (26) is defined like explanation of drawing 1 . An equalizer [of the latter part in drawing 18] 21-1, —, according [21-N] to signal symbol (bn (k), and [bn (k-1), —, bn] (K-Q +1) (n= 1, —, N)) of each user's self intersymbol-interference channel is equalized. Therefore, in the equalizer 71 of the preceding paragraph, processing which removes interference other than the above (bn (k), and [bn (k-1), —, bn] (K-Q +1) (n= 1, —, N)) in y (k) is performed. The quantitive explanation is given to below.

[0088] First, a decoder 24-1, --, prior information lambda2 p of the equalizer 71 fed back from 24-N It asks for soft decision transmitting symbol presumption b' (k) by the formula (15) using [bn (k)] (n= 1, --, N). Next, these soft decision transmitting symbol b'n Replica H-B[of an interference signal] ' (k) is created using (k) and the channel matrix H, and it subtracts from receiving vector y (k).
y'n(k) **y(k)-H-B' (k) (27) ' B'(k) =[b'T --(k+Q -1) b'T (k) --b'T] (k-Q +1) T H-(B(k)-B' (k)) +n (k) and (28) ' -- = here (29) -- ' -- and b'(k+q) =[b'1 b(k+q) '2 (k+q) -- b'n --(k+q) b'N (k+q)]T : q=Q- 1, --, 1 (53) b'(k+q) =[b'1 b(k+q) '2 --(k+q) 0 --b'N] (k+q) T : q= 0 and -- -Q+1 (54)
(The zero in the element of b' (k+q) are the n-th)
Actuation of subtracting this interference below will be called software interference cancellation. y'n (k) which will be obtained after subtraction supposing the replica of an interference signal is made ideally is the n-th user's symbol bn. (k), A formula (54) shows q= 1, --, that it cannot have in having set the n-th element of b' (k+q) to 0 by -Q+1 only with the intersymbol-interference component by a user's n-th own symbol [bn (k-1), --, bn] (k-Q +1) of ********.
[0089] Although the contribution component from the signal of the n-th user (transmitter) within the receiving vector r (k) is based on a symbol (bn (k), and [bn (k-1), --, bn] (k-Q +1)), it actually sees. But So that I may be understood from the definition of receiving vector [of a formula (21)] y (k) In the contribution component from the signal of the n-th user (transmitter) in receiving BEKURUTOy (k) which compounds by the multi-pass and is made, it is the k-th symbol bn. This is received if based on (k). Symbol [bn (k+Q -1) of the future, bn (k+Q -2), --, the intersymbol-interference component by bn (k+1)] will also be included. That is, the above-mentioned interference replica has also included the interferent component from the future. thus, the difference of formula (27) ' -- vector y' (k) -- the difference of a formula (27) -- it differs from vector y' (k).
[0090] Then, the next step of the preceding paragraph processing in an equalizer 71 is the interference surplus component after software interference cancellation, i.e., the residual interferent component based on said imperfect composition of interference replica H-B' (k), and said future intersymbol-interference component y'n The linearity filter of an MMSE (2nd [an average of] power error of the minimum) norm removes from (k). That is, filter shape wn y'n It is made for the result of having carried out filtering of the (k) as shown in a formula (55) to become equal to channel value alpha1n, alpha2n, --, the sum that carried out the multiplication of the alphaQn, respectively as the symbol in the signal of the n-th user in an input signal (bn (k), and [bn (k-1), --, bn] (K-Q +1)).
wn H (k) and y'n (k) **sigmaq=0 Q-1 alphaq (k) and bn =(k-q) alphan H (k) and bn (k) (55)
Therefore, this filter shape wn (k) and channel value (channel information) alphan after identification What is necessary is just to calculate a formula (55) in quest of (k). It is wn below. (k) and alphan The calculation approach of (k) is shown. In addition, filter shape wn (k) is the filter factor wn given by the formula (32) and the formula (34). Although it differs from (k), the same notation is used for convenience.
[0091] The above-mentioned solution is defined as a solution of the following optimal problems.
(wn (k) alphan (k)) =arg min ||wn H (k) and y'n (k)
- alphan H (k) and bn (k) ||2 (56)
It is contingent [on alpha1n(k) =1]. That is, wn from which the right-hand side of a formula (56) serves as min (k) and alphan It asks for (k). Constraint alpha1n(k) =1 added is alphan. (k) =0 and wn It is for avoiding the becoming solution (k) =0. This is ||alphan. Although solving by the constraint which becomes (k) ||2 =1 is also possible, below, it is alpha1n. The solution in (k) =1 is shown. Since it is easy, a problem is replaced as follows. That is, mn which makes the right-hand side of a formula (56) min about w and alpha It is defined as (k).
[0092]
mn (k) =arg min ||mn H (k) and zn (k) ||2 (57)
mn H It is contingent [on (k) and eMQ+1=-1]. (alpha1n(k) =1 and equivalence)
here -- mn (k) **[wn T (k), -n[alpha] (k) T] T (58)
zn (k) **[yn T (k) b(k) n T] T (59)
eMQ+1= [0--1--0] T (60)

(— the element of one in eMQ+1 is MQ+1st). The solution of this optimization problem is given below from reference [2] S.Haykin, Adaptive Filter Theory, and the Lagrange method of undetermined coefficients shown in Prentice Hall P.220-P227.

[0093]

mn (k) =-RZZ-1 and eMQ+1/(eMQ+1H, RZZ-1, and eMQ+1) (61)

It is here. RZZ=epsilon [zn (k) and zn H (k)] (62)

epsilon [A] expresses the expected value (average) of A.

[0094]

[Equation 21]

$$= E\begin{bmatrix} H \cdot \Lambda_n(k) \cdot H^H + \sigma^2 I & H_n^H \\ H_n & I \end{bmatrix} \quad (63)$$

[0095]

lambdan (k) =diag [Dn (k+Q -1), --, Dn (k), --, Dn] (k-Q +1) (64) I is a unit matrix. sigma2 Noise power (variance of white nature Gaussian noise)

[0096]

[Equation 22]

$$H_n = \begin{bmatrix} h_n(Q-1) & 0 & 0 & 0 \\ h_n(Q-2) & h_n(Q-1) & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots \\ h_n(0) & h_n(1) & \cdots & h_n(Q-1) \end{bmatrix} \quad (65)$$

[0097]

Dn =(k+q) diag [1-b'1 2 (k+q), —, 1-b'n 2 (k+q), —, 1-b'N 2] (k+q) : q=Q +1 and — one (66) Dn = (k+q) diag[— 1-b'1 — 2 (k+q), —, 1, —, 1-b'N 2] (k+q) : q= 0, —, -Q+1 (67)

diag expresses a diagonal matrix (elements other than the element of the diagonal line of a matrix are zero). That is, it is mn if the channel matrices H and sigma2 are known. It can ask for (k) by the formula (61). Therefore, a formula (58) is followed and it is wn. (k) and alphan (k) is called for.

[0098] This computed filter shape wn By (k), it is y'n. Filtering of the (k) is carried out by the degree type.

un (k) =wn H (k) and y'n (k) (68)

H expresses a conjugate transposed matrix. This n processing result by which filtering was carried out is sent to equalizer 21-n to which consecutiveness corresponds. Thus, the left part of the formula (1) from the n-th user and the corresponding input signal un (k) is obtained, the channel value hmn (q) of the right-hand side of a formula (1) and corresponding alphamn (k) are obtained, that is, a formula (1) and a corresponding formula (55) can be found. Therefore, alphan (k) is given to consecutive equalizer 21-n as an equalizer parameter (channel value). The above is preceding paragraph processing by the equalizer 71.

[0099] Next, the processing after consecutive equalizer 21-n is described. As mentioned above, since it corresponds with the formula (1), since it is shown in reference [1], a formula (55) omits actuation within equalizer 21-n for every user for details, as stated also above that what is necessary is just to carry out like actuation of the equalizer 21 in drawing 31 . un which defined each equalizer 21-n by the top (k) and alphan the logarithm of the probability for the prior information lambda 2 from (k) and decoder 24-n [bn (k)] to be inputted, and for each coding bit to be +1 as an output, and the probability which is -1 — a likelihood ratio lambda 1 (LLR:Log-Likelihood Ratio) is computed by the degree type.

[0100]

[Equation 23]

$$\Lambda_1[b(k)] = \log\frac{\Pr[b_n(k)=+1 \mid u_n(k), k=0,\cdots,B]}{\Pr[b_n(k)=-1 \mid u_n(k), k=0,\cdots,B]} \quad (69)$$

$$\equiv \lambda_1[b_n(k)] + \lambda_2^p[b_n(k)] \quad (70)$$

[0101] It is lambda 1 here. [bn (k)] is the external information and lambda2p which are sent to consecutive decoder 24-n. [bn (k)] is prior information given to an equalizer 31. decoder 24-n — a logarithm — likelihood ratio lambda 2 It computes by the degree type.
[0102]
[Equation 24]

$$\Lambda_2[b_n(i)] = \log\frac{\Pr[b_n(i)=+1 \mid \lambda_1[b_n(i)], i=0,\cdots,B]}{\Pr[b_n(i)=-1 \mid \lambda_1[b_n(i)], i=0,\cdots,B]} \quad (71)$$

$$\equiv \lambda_2[b_n(i)] + \lambda_1^p[b_n(i)] \quad (72)$$

[0103] It is lambda 2 here. [bn (i)] is the external information and lambda1 p which are given to an equalizer 71 and an equalizer 21 in the case of a repeat. [bn (k)] is the prior information given to decoder 24-n. The configuration shown in this drawing 18 performs identification and decode repeatedly, and improvement in an error rate is attained. The functional configuration of the multiuser equalizer 71 mentioned above is briefly explained with reference to drawing 19 . each — an antenna — an input signal — a receive section — 70 — a vector — r — (— k —) — = — [— r — one — (— k —) — rM — (— k —) —] — ****** — processing — having — this — a vector — r — (— k —) — using — reception — a vector — generation — the section — 311 — setting — each — a multi-pass (channel) — having taken into consideration — a formula — (— 21 —) — reception — a vector — y — (— k —) — generating — having .
[0104] On the other hand, input-signal [from a receive section 70] r (k), and each transmitter from the unique WORD storage section 29 and the corresponding known sequence signals, such as a unique WORD sequence for channel presumption, are inputted into the channel presumption machine 28, and the channel matrix H is presumed. moreover, the output of each decoder 24-1, —, 24-N — a logarithm — likelihood ratio lambda2 [b1 () [bN (k)] is inputted into the soft decision symbol presumption section 313-1, —, 313-N. i) —], —, lambda2 (k)], —, lambda 2 — [bN from (i)] — respectively — prior information lambda1 p [— b1 (i)], —, lambda1p [bN External information lambda 2 from which (i)] was deducted [— b1 It is the soft decision transmitting symbol b'1 by the formula (15), respectively. (k), —, b'N (k) is calculated. These are inputted into the interference vector generation section 72, and vector B[of the symbol estimate which can serve as an interference signal from other transmitters for every n] ' (k) is generated by formula (29) ', (53), and (54) in the interference vector generation section 72. The product of vector B' (k) and the channel matrix H of these N individual calculates, respectively by the other interference signal estimation section 73-1, —, 73-N, and replica H-B (k) of an interferent component is calculated.
[0105] interferent component replica H-B (k) of these N individual subtracts from receiving vector y (k) by the subtraction section 74-1, —, 74-N, respectively — having — difference — a vector y'1 (k), —, y'N (k) is called for. Soft decision transmitting symbol b'1 (k), —, b'N (k) is inputted into the error matrix generation section 75. It is the error matrix lambda 1 by the formula (64), (66), and (67). (k), —, lambdaN (k) is generated. These, the channel matrix H, and noise power sigma2 It is inputted into the filter shape presumption section 76, and is a filter shape wn at the filter shape presumption section 76 by a formula (58), (60), (61), (63), and (65). Channel information alphan after identification It is presumed. these filter shapes w1, — and wN difference — vector y'1 (k) — — and y'N The multiplication of the (k) is carried out by the filtering section 77-1, —, 77-N, respectively. Filtering is carried out. That is, symbol [bn (k) from

each pass for every user, u1 which is bn (k-1), —, the component of which interference [signal / other user] was removed from the input signal of bn (K-Q +1)] (k), — and uN Channel information alpha 1 after the identification which (k) was obtained, respectively and was asked for it in these and the filter shape presumption section 76 (k), —, alphaN (k) is supplied to the single user equalizer 21-1 in drawing 18 , —, 21-N, respectively.

[0106] The procedure of the 1st invention (2) of this turbo receiving method is shown in drawing 20 . The same step notation was attached to the procedure shown in drawing 3 , and a corresponding step in drawing 20 . However, interference replica vector B'n in step S4 Formula (29) ', (53), and (54) perform count of (k). Step S13 is soft decision transmitting symbol b'n. (k) is used and it is error matrix lambdan by the formula (64), (66), and (67). (k) is generated. Step S14 is a channel, Matrix H, and noise power sigma2. Error matrix lambdan (k) is used and it is the residual interference removal filter wn by a formula (58), (60), (61), (63), and (65). (k) and channel information alphan It asks. step S15 — difference — vector y'n (k) — residual interference removal filter shape wn (k) — filtering — carrying out — un It asks for (k). step S16 — each filtering result un (k) — receiving — single user identification processing — carrying out — a logarithm — likelihood ratio lambdan It asks for [bn (k)], respectively and decode processing of these is carried out at step S10. Others are the same as that of the processing shown in drawing 3 .

[0107] Although the identification range in latter-part equalizer 21-n is made into the intersymbol-interference section by the symbol (bN (k), and [bn (k-1), —, bn] (K-Q +1) (n= 1, —, N)) in ****, this identification range can be adjusted. For example, as for the case of a very big value, the count load of latter equalizer 21-n becomes [Q] large. In such a case, what is necessary is to set the identification range of latter-part equalizer 21-n to Q'<Q, and just to change so that the equalizer 71 of the preceding paragraph may remove the intersymbol interference of the signal of the same users other than bn (k), and [bn (k-1), —, bn] (K-Q'+1) (Q'<Q, n= 1, —, N) section. This modification is explained later. As it divides into this preceding paragraph identification and latter-part identification and a broken line also shows a **** case in drawing 19 R> 9, in the channel presumption machine 28, the symbol storage section 32 is formed last time, and it is hard decision transmitting symbol b^n. As a channel value is presumed using (k), that presumed precision can be raised.

[0108] Signal un of N sequence which carried out identification separation of the interference [train / other-system] for these to the sending signal of N sequence in the multi-output equalizer 71 of the preceding paragraph in the example shown in drawing 17 Channel information alphan after identification It outputs and is the signal un of after that and N sequences each. Latter single user equalizer 22-n removed the intersymbol interference of the same sending signal. That is, it considered as two steps of concatenation identification configurations. It is good also as three or more steps of concatenation multistage configurations. For example, input signal rm of an M sequence [as opposed to / in / as shown in drawing 21 / the equalizer 81 of the 1st step / the sending signal of N sequence] Identification signal sequence er1 which inputted and removed interference by the No. [U+1] transmitting sequence of the 1st - a No. [U] transmitting sequence (k) and channel information e[after the identification] alpha (k), Identification signal sequence er2 which removed interference by the 1st of the U+1st - a No. [N] transmitting sequence - the No. [U] transmitting sequence (k) and channel information ealpha2 after the identification (k) is obtained. In 82-1 in the equalizer 82-1 of the 2nd step, and 82-2 inputted er1 (k) and ealpha1 (k) — identification processing — carrying out — the [the 1st in the 1st - a No. / U / transmitting sequence -] — U1 the Uth of a watch transmitting sequence — identification signal sequence er3 which removed interference by 1+1 - the No. [U] transmitting sequence Channel information ealpha3 after (k) and its identification With (k) the Uth in the 1st - a No. [U] transmitting sequence — the [1+1 -] — U2 the [1st / of a watch transmitting sequence / the / -] — the [U No. 1 transmitting sequence and] — identification signal sequence er4 which removed interference by U2 - the No. [U] transmitting sequence Channel information ealpha4 after (k) and its identification With (k) the Uth in the 1st - the Uth transmitting sequence — the [the 1st of 2+1 - the Uth transmitting sequence -] — U2 Identification signal sequence er5 which removed interference by the transmitting sequence

Channel information ealpha5 after (k) and its identification (k) is outputted, respectively.
[0109] With the equalizer 82-2 of the 2nd step, it is the identification signal sequence er2 similarly. (k) and channel information ealpha2 (k) is inputted and it is the identification signal sequence er6. (k) and channel information ealpha6 after identification (k) and identification signal sequence er7 (k) and channel information ealpha7 after identification (k) is outputted. In the case of N= 5, the equalizer 83-1 to 83-5 of the 3rd step turns into a single user equalizer in drawing 18 . Or the input identification signal of an equalizer 83-3 may be constituted by two sending signals, may remove the mutual intervention between the two sending signals with an equalizer 83-3, and may equalize 2 sets of identification signals, and the channel information after the identification, respectively by the following single user equalizer 84-1 and 84-2. Furthermore, for example with an equalizer 83-4, it is the identification signal er6. (k) and channel information ealpha6 (k) may be inputted and a mutual intervention with other two sending signals and the intersymbol interference by the multi-pass of itself may be removed about all the configuration sending signals, for example, each of three sending signals. You may constitute from one thru/or the plurality of the equalizer 82-1 of the 2nd step, and 82-2 so that each identification signal over two or more sending signals may be acquired at once.
[0110] Generally two or more identification signal sequences and the group of after [identification] channel information are outputted from the equalizer of the 1st step as mentioned above. the group of the channel information after each identification signal sequence and its identification — 1 thru/or two or more equalizers — 1 — or two or more steps are concatenated — making — final — the 1- each identification output of the Nth transmitting sequence, i.e., this example, — a logarithm — likelihood ratio lambda 1 [bn (k)] can also be made to output. Thus, when performing multistage concatenation identification processing, it is desirable for the latter part to make smallness the value of numbers-of-passes Q which carries out interference removal, as mentioned above, and to lessen the amount of data processing. In this case, as mentioned above, an interferent component with the pass which decreased in number in the latter part is removed in the identification stage in front of that.
[0111] In the following with the equalizer 21 of the 1st step in drawing 21 The transmitting sequence of N individual, the number of the multi-passes of each transmitting sequence — identification signal sequence er1 of the group of the input signal of Q to U transmitting sequences Channel information ealpha1 after (k) and identification (k) is obtained and identification processing with the equalizer 82-1 of the latter part explains the identification processing in the case of making the number of the multi-passes of each transmitting train system into Q'. Although interference vector B' (k) is generated in the interference vector generation section 72 almost like the example shown in drawing 18 and drawing 19 , this constructive mood (53) and a formula (54) change into formula (53) and formula (54) ' and a formula (73).
[0112]
b'(k+q) =[b'1 b(k+q) '2 — (k+q) b'n (k+q)
— b'N (k+q)]T : q=Q -1, --1 (53)
b'(k+q) = [0 --0 b' U+1 (k+q) --b'N] (k+q) T : q= 0, --, -Q'+1 (54) ' b'(k+q) =[b'1 b(k+q) '2 — (k+q) b'n (k+q)
— b'N (k+q)]T : q=Q', —, -Q+1 (73) Formula (54) ' is for equalizing except for the self and the mutual intersymbol-interference component of each [these] sequence based on the symbol of the 1st - the Uth transmitting sequence itself, and the multi-pass of Q'. A formula (73) is for removing the self and the mutual intersymbol interference of the 1st - the Uth transmitting sequence based on the Q'+1st thru/or the Qth pass in order to decrease the number of multi-passes to Q' by latter identification.
[0113] Thus, interference signal replica H-B' (k) is made using obtained interference vector B' (k), and this is subtracted from receiving vector y (k), that is, a degree type is calculated. y'g (k) **y(k)-H-B' (k) Actuation of subtracting this interference below (27) ″ =H-(B(k)-B' (k)) +n (k) and (28)″ will be called software interference cancellation. y'g which will be obtained after subtraction supposing replica H-B[of an interference signal] ' (k) is made ideally It turns out that (k) cannot have only the signal component of bn (k), [bn (k-1), —, bn] (k-Q'+1), and (n=1-U).

[the symbol of the 1st – the Uth transmitting sequence,]
[0114] Next, the linearity filter of an MMSE norm removes the interference surplus component after software interference cancellation like the above-mentioned. The formula in this case (55) and the corresponding formula become degree type (55) '.
wg H (k) and y'g (k) **sigman=1 U sigmaq=0 Q'−1alphanq(k) and bn =(k−q) alphag H (k) and bg (k) (55) ' — here, alphag (— k —) — = — [— alpha — one — zero — (— k —) — alpha — one — Q — ' – one — (— k —) — alpha — U — zero — (— k —) — alpha — U — Q — ' – one — (– – k —) —] — T — (55-1)
bg (— k —) — = — [— b — one — (— k —) — b — one (k−Q'+1) — bU — (— k —) — bU —] (k−Q'+1) — T — (55-2)
These [wg] (k) and alphag wg from which the right-hand side serves as min by making a formula (56) into a degree type like [also asking for (k)] the above-mentioned (k) and alphag It asks for (k).
[0115]
(wg (k) alphag (k)) =arg min ||wg H (k) and y'g (k)−alphag H (k) and bg (k) ||2 (56) 'alpha — 1 and 0 It is contingent [on (k) =1]. the added constraint — alphag (k) =0 and wg (k) =0 — in order to avoid a solution — it is — ||alphag (k) ||2 =1 — although solving by the constraint is also possible — the following — alpha — 1 and 0 In the case of (k) =1, a problem is replaced as follows.
mg (k) =arg min ||mg H (k) and zg (k) ||2 (57) 'mg H It is contingent [on (k) and eMQ'+1 =−1]. Here, it is mg. (k) **[wg T (k)−alphag T (k)] T (58) ' zg (k) **[yg T (k) b(k) g T] T (59) ' eMQ'+1 = [0 — 1 — 0] T (60) ' (eMQ' +1 element of inner one MQ' the +1st)
The solution of this optimization problem is given below from the Lagrange method of undetermined coefficients shown in said reference [2].
[0116]
mg (k) =−Rzz−1 and eMQ'+1/(eMQ'+1 H, Rzz−1, and eMQ'+1) [(61) ' — here — 0117]
[Equation 25]

$$R_{zz} = E[\, z_g(k)\cdot z_g^H(k)] \qquad (62)'$$

$$= E\begin{bmatrix} H\cdot\Lambda(k)\cdot H^H + \sigma^2 I & H_g^H \\ H_g & I \end{bmatrix} \qquad (63)'$$

[0118]
lambdan (k) =diag [Dn (k+Q −1), —, Dn (k), —, Dn] (k−Q +1) (64) ' [0119]
[Equation 26]

$$H_g = \begin{bmatrix} h_1(Q-1) & 0 & 0 & \cdots & h_U(Q-1) & 0 & 0 \\ h_1(Q-2) & \ddots & 0 & \cdots & h_U(Q-2) & \ddots & 0 \\ h_1(Q-3) & \vdots & h_1(Q-1) & \cdots & h_U(Q-3) & \vdots & h_U(Q-1) \\ \vdots & \vdots & \vdots & \cdots & \vdots & \vdots & \vdots \\ h_1(0) & \cdots & h_1(Q'-1) & \cdots & h_U(0) & \cdots & h_U(Q'-1) \end{bmatrix} \qquad (65)'$$

[0120]
Dn =(k+q) diag [1−b'1 2 (k+q), —, 1−b'n 2 (k+q), —, 1−b'N 2] (k+q) : q=Q+ — 1, —, 1 (66)
Dn =(k+q) diag [1, —, 1, and 1−b'U +12 (k+q), —, 1−b'N 2] (k+q) : q= 0, —, −Q'+1 (67) ' Dn =(k+q) diag [1−b'1 2 (k+q), —, 1−b'n 2 (k+q), —, 1−b'N 2] (k+q) : q=Q', ——Q+1 (74)
That is, it is mg if a channel parameter is known. It can ask for (k) by formula (61) '. Furthermore, formula (58) ' is followed and it is wg. (k) and alphag (k) and (=ealpha1 (k)) are called for. Such count is performed in the filter shape presumption section 76 in drawing 19 , and filtering of the degree type is calculated and carried out in the filtering section 77-1.
[0121]
er1 (k) =wg H (k) and y'g (k)
This identification output er1 (k) and after [identification] channel information ealpha1 (k)

=alphag (k) is sent to the latter equalizer 82-1. When dividing [for example,] into a 3 transmitting sequences (user) group and a 2 transmitting sequences (user) group as mentioned above at the time of the transmitting sequence (user) of 5 It reaches U=3, the above-mentioned algorithm is performed by 2, and they are these two identification outputs er1. (k), ealpha1 (k) and er2 (k) and ealpha2 It inputs into the equalizer the object for 3 transmitting sequences (user) of consecutiveness to (k), and for 2 transmitting sequences (user), and the identification output of each transmitting sequence (user) is obtained, respectively.

[0122] Moreover, it is applicable also to the single user turbo equalizer receiver shown in drawing 8 , the RAKE composition processing turbo receiver shown in drawing 9 , a turbo receiver equipped with the adaptive array antenna receive section which showed drawing 10 , and a turbo receiver equipped with the channel presumption machine 42 still more generally shown in drawing 12 to make the error correction decode result of the signal which was mentioned above and to detect reflect in a soft decision transmitting symbol. Furthermore, although the symbol hard decision value judged to be probable by presumption of the 2nd henceforth of the channel matrix H and covariance-matrix U^ was also used as a reference sign in drawing 13 , drawing 14 , and drawing 15 , 2nd henceforth may make only unique WORD a reference sign, covariance-matrix U^ may be presumed using a formula (51), and channel presumption using a symbol hard decision value and presumption of covariance-matrix U^ may be omitted.

the 1st invention (2) (juxtaposition transmission) -- transmitting information sequence c (i) by one user as two or more juxtaposition sequences next -- frequency use -- performing high-speed transmission efficiently is proposed. The example of the turbo receiver which applied this invention is explained to such a sending signal.

[0123] It sets to a transmitting side so that the same reference mark may be attached with drawing 1 at the part corresponding to drawing 22 and it may be shown. As for modulation output-signal [from a modulator 13] b (j), the sequential distribution of the each symbol b (j) are carried out by the serial-parallel transducer 14 at the sequence of N individual. Sequence signal b1 of two or more integer N individuals (k), --, bN Although it is referred to as (k) and shown in drawing, after these are changed into the signal of a radio frequency, they are transmitted from the antenna of N individual. The sequence signal of these N individual is received by the turbo receiver of this invention through a channel (transmission line). the receiving antenna of this receiver -- one or more pieces -- it is -- this input signal -- baseband digital input signal rm of one or more integers [M] (k) -- (-- m= -- it is inputted into the multi-output equalizer 31 as 1, 2, --, M). Input signal rm (k) is generated as shown in drawing 28 .

[0124] The processing the multi-output equalizer 31 is the same as that of the configuration shown in drawing 2 , and same as the procedure shown in drawing 3 is performed. the logarithm from the decoder 24 shown in drawing 22 on that occasion -- likelihood ratio lambda 2 [b (i)] to external information lambda 1 [bi] is subtracted with a subtractor 25. The interleave of the subtraction output is carried out by INTARIBA 26, and it is the prior information lambda 2. It is referred to as [b (j)]. The prior information lambda 2 [b (j)] is the prior information lambda 2 on N sequence at the serial-parallel converter 15. [b1 (k)], --, lambda 2 It is changed into [bN (k)] and is inputted into the multi-output equalizer 31.

[0125] therefore, in the multi-output equalizer 31, the input signal of the M sequence carries out linear equalization processing similarly with having stated previously -- having -- the logarithm of N individual -- likelihood ratio sequence lambda 1 [b1 (k)], --, lambda 1 [bN (k)] is outputted. the logarithm of this N individual sequence -- a likelihood ratio sequence -- the juxtaposition-serializer 16 -- the logarithm of one sequence -- likelihood ratio sequence lambda 1 It is changed into [b (j)] and a subtractor 22 is supplied. By identification processing which the input signal format of the multi-output equalizer 31 became being the same as that of what was explained by drawing 1 thru/or drawing 3 according to this configuration, therefore was performed with reference to drawing 1 thru/or drawing 3 the logarithm of N sequence -- likelihood ratio lambda 1 [b1 (k)], --, lambda 1 He can obtain [bN (k)] and it will be easily understood by using the serial-parallel converter 15 and the parallel-serial-conversion machine 16 that decode processing can be performed repeatedly. In drawing 1 thru/or drawing 3 , identification of the n-th sending signal (eye n train) in the juxtaposition sending signal of N

individual will be carried out in this case corresponding to the sending signal of the n-th transmitter. Moreover, it can be understood easily that the example which referred to drawing 4 thru/or drawing 7 R> 7 is also applicable about the reception to juxtaposition transmission of this N sequence signal. Moreover, by concatenation-processing by two or more identification stages shown in drawing 18 thru/or drawing 21 , a receiving property improves compared with processing by the single identification stage shown in drawing 1 thru/or drawing 31 .

[0126] The turbo receiving approach of this invention and a receiver are applicable also to the reception to a convolutional code / turbo sign + INTARIBA + multi-level modulation (QPSK, 8PSK, 16QAM, 64QAM, etc.), the TCM (Trellis Coded Modulation)/turbo TCM, etc.
By generation **** of M input signals, they are M input signals r1. (k), --, rM Although it asked for (k) from M antenna #1, --, #M, you may ask from one antenna or may ask for many M input signals from L from the input signal of the antenna of two or more integers [L]. although drawing 1 was not especially shown -- each -- the input signal from antenna #1, --, #M -- a baseband transducer -- input signals r1, --, rm of baseband ** -- it is carried out and samples -- having -- digital signal r1 of the discrete time of day k (k), --, rM It is referred to as (k).

[0127] For example, the input signal received by L= 2 antenna #1 and #2 as shown in drawing 30 B is changed into baseband signaling by the baseband transducer 61-1 and 61-2, respectively. The baseband transducer 61-1 and each output of 61-2 the sampling signal and this sampling signal from the sampling signal generator 62 with the sampling signal which shifted the phase only T/2 of those periods T with the phase shifter 63 It is sampled by A/D converter 64-1, 64-2 and 64-3, and 64-4, respectively, and is a digital signal r1. (k), r2 (k) and r3 (k) and r4 It is changed into (k), and is inputted into the turbo receiver 30 shown in drawing 1 , drawing 18 , or drawing 22 , and you may make it obtain the decode output of N individual. In addition, input signal r1 inputted into the turbo receiver 30 (k), --, r4 Each sampling period of (k) is one input signal rm per one antenna. The frequency of the sampling signal from the sampling signal generator 62 is selected so that it may be in agreement with the sampling period in the case of receiving (k).

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] Drawing showing the functional configuration of a system including the example of the turbo receiver of this 1st invention.
[Drawing 2] Drawing showing the example of a concrete functional configuration of the multi-output equalizer 31 in drawing 1 .
[Drawing 3] The flow chart showing the example of the turbo receiving approach of this 1st invention.
[Drawing 4] Drawing in which A shows the example of a frame structure, and B are drawings showing the processing in each repeat for explaining the repeat channel presuming method in the 4th invention.
[Drawing 5] Drawing showing the example of a functional configuration for taking out a probable hard decision symbol.
[Drawing 6] The flow chart showing the example of the procedure of repeat channel presumption in this invention.
[Drawing 7] Drawing showing some examples of a functional configuration of the equalizer 31 in the 2nd invention in which the error correction decode result of the signal which A detects is made to reflect, and B are drawings showing the example of the procedure.
[Drawing 8] Drawing showing the example of the receiver performed by repeating a turbo equalizer.
[Drawing 9] Drawing showing the example of the receiver which performs the repeat of RAKE receiving-turbo decode.
[Drawing 10] Drawing showing the example of the receiver which performs the repeat behind an adaptive array antenna receiving-turbo.
[Drawing 11] Drawing showing the outline of a turbo equalizer and a turbo decoder.
[Drawing 12] Drawing showing the outline of the receiver which repeats the processing using a presumed channel, and its processed decode processing of a signal to an input signal.
[Drawing 13] The flow chart showing the example of the procedure of the outline of the receiving approach which repeats the processing using a presumed channel, and its processed decode processing of a signal to an input signal.
[Drawing 14] Drawing in which A shows the example of a frame structure, and B are drawings showing repeat processing of presumption of the Channel H and the noise covariance matrix U in the case of including noises other than the white nature Gaussian random noise in an input signal.
[Drawing 15] Drawing showing some examples of a functional configuration of the equalizer using presumption of the noise covariance matrix U.
[Drawing 16] The flow chart showing the example of the procedure which repeats decode processing with channel value presumption using presumption of the noise covariance matrix U.
[Drawing 17] Drawing showing the principle of the turbo receiver by this 3rd invention.
[Drawing 18] Drawing showing the example of a functional configuration of the turbo receiver by this 3rd invention.
[Drawing 19] Drawing showing the example of the functional configuration of the multiuser

(preceding paragraph) equalizer 71 in drawing 18 .
[Drawing 20] The flow chart showing the example of the procedure of the turbo receiving approach by this 3rd invention.
[Drawing 21] Drawing showing other examples of a functional configuration of the multistage identification part in the 3rd invention.
[Drawing 22] Drawing showing the example of a system configuration to which the example of the 1st invention (2) was applied.
[Drawing 23] The error rate property Fig. of the turbo receiver which applied the 1st invention (1) (assuming that the channel was presumed completely, a part for Eb(bit energy):2 user No is noise energy).
[Drawing 24] Drawing showing the error rate property at the time of changing a threshold (Th) and performing channel presumption repeatedly.
[Drawing 25] The error rate property Fig. of the turbo receiver using [on the 4th invention and] especially repeat channel presumption.
[Drawing 26] Drawing showing the error rate property of the turbo receiver using presumption of the noise covariance matrix U.
[Drawing 27] Drawing showing the error rate property of the turbo receiver shown in drawing 1 .
[Drawing 28] Drawing showing the error rate property of the example of the 2nd invention in which the error correction decode result of the signal to detect was made to reflect.
[Drawing 29] Drawing showing the simulation result of the error rate property of the turbo receiver of this 3rd invention.
[Drawing 30] Drawing showing the concept of a MIMO system.
[Drawing 31] Drawing showing the functional configuration of the conventional turbo transmitter-receiver for single users.

[Translation done.]

(19)日本国特許庁（ＪＰ）　(12) **公開特許公報**（Ａ）　(11)特許出願公開番号
特開2003－152603
（P2003－152603A）
(43)公開日　平成15年５月23日(2003.5.23)

(51)Int.Cl.⁷	識別記号	ＦＩ	テーマコード*(参考)
Ｈ０４Ｂ　3/06		Ｈ０４Ｂ　3/06	Ｅ　５Ｋ０１４
7/005		7/005	５Ｋ０２２
Ｈ０４Ｊ　13/00		Ｈ０４Ｌ　1/00	Ｂ　５Ｋ０４６
Ｈ０４Ｌ　1/00		Ｈ０４Ｊ　13/00	Ｚ

審査請求　有　　請求項の数35　ＯＬ　（全 45 頁）

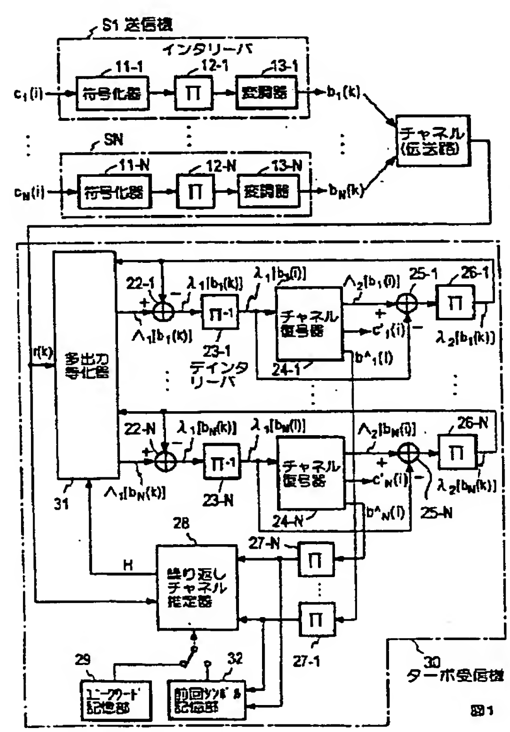
(21)出願番号　特願2002－10839(P2002－10839)
(22)出願日　平成14年１月18日(2002.1.18)
(31)優先権主張番号　特願2001－43213(P2001－43213)
(32)優先日　平成13年２月20日(2001.2.20)
(33)優先権主張国　日本（ＪＰ）
(31)優先権主張番号　特願2001－111095(P2001－111095)
(32)優先日　平成13年４月10日(2001.4.10)
(33)優先権主張国　日本（ＪＰ）
(31)優先権主張番号　特願2001－258161(P2001－258161)
(32)優先日　平成13年８月28日(2001.8.28)
(33)優先権主張国　日本（ＪＰ）

(71)出願人　392026693
株式会社エヌ・ティ・ティ・ドコモ
東京都千代田区永田町二丁目11番１号
(72)発明者　藤井　啓正
東京都千代田区永田町二丁目11番１号　株式会社エヌ・ティ・ティ・ドコモ内
(72)発明者　阿部　哲士
東京都千代田区永田町二丁目11番１号　株式会社エヌ・ティ・ティ・ドコモ内
(74)代理人　100066153
弁理士　草野　卓　（外１名）

最終頁に続く

(54)【発明の名称】　ターボ受信方法及びその受信機

(57)【要約】
【課題】　多入力多出力（複数ユーザ）の受信を可能とする。
【解決手段】　Ｍ個の受信信号 r_m （ｍ＝１，…，Ｍ）と、既知信号により、各伝送路インパルス応答 $h_{mn}(q)$ を推定し（ユーザ数Ｎ，ｎ＝１，…，Ｎ）、$h_{mn}(q)$ を要素とするＭ×Ｎ行列 $\mathbf{H}(q)$ 、その $\mathbf{H}(q)$ を要素とするＱ×Ｑ行列 $\mathbf{H}$ を求め（Ｑは各送信波のマルチパスの数、ｑ＝０，…，Ｑ－１）、復号 $\lambda_2[b_n(k)]$ により軟判定値 $b'_n(k)$ を求め、これを用いて干渉成分ベクトル $\mathbf{B}'(k)$ を作り、干渉レプリカ $\mathbf{H}\cdot\mathbf{B}'(k)$ を求め、これを受信ベクトル $\mathbf{y}(k)$ から引き、$\mathbf{y}'(k)$ を求め、$\mathbf{y}(k)$ と $\mathbf{H}$ を用いて最小平均２乗誤差規範で $\mathbf{y}'(k)$ 中の残余干渉成分を除する、ｎ番目のユーザに対する適応フィルタ $\mathbf{w}_n(k)$ を求め、$\mathbf{y}'(k)$ を $\mathbf{w}(k)$ に通して干渉除去されたユーザｎからの受信信号として対数尤度比を得る。



【特許請求の範囲】

【請求項1】 2以上の整数N個の送信機からの信号を受信するターボ受信方法であって、

1以上の整数M個の受信信号 r_m と、既知信号とから、チャネル値 $h_{mn}(q)$ 及びチャネル行列 $\mathbf{H}$ を計算し、

ここで、m=1，…，M、n=1，…，N、q=0，…，Q−1、Qは各送信電波のマルチパスの数

N個の事前情報 $\lambda_2[b_n(k)]$ から軟判定送信シンボル $b'_n(k)$ を求め、ここでkは離散的時刻、

チャネル値 $h_{mn}(q)$ と軟判定送信シンボル $b'_n(k)$ を用いて、n番目の送信機の送信信号に対する干渉成分 $\mathbf{H}\cdot\mathbf{B}'(k)$ を計算し、

ここで

【数1】

$$\mathbf{H}=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & \ddots & \\ 0 & & H(0) & \cdots H(Q-1) \end{bmatrix}$$

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix}$$

$\mathbf{B}'(k)=[\mathbf{b}'^T(k+Q-1)\cdots\mathbf{b}'^T(k)\cdots\mathbf{b}'^T(k-Q+1)]^T$

$\mathbf{b}'(k+q)=[b'_1(k+q)\ b'_2(k+q)\cdots b'_N(k+q)]^T$

q=Q−1……−Q+1 q≠0で

$\mathbf{b}'(k)=[b'_1(k)\cdots 0\cdots b'_N(k)]^T$

q=0で

$\mathbf{b}'(k)$ の要素のゼロはn番目であり、$[\ ]^T$は転置行列であり、

この干渉成分 $\mathbf{H}\cdot\mathbf{B}'(k)$ を受信ベクトル $\mathbf{y}(k)$ から差し引き差分ベクトル $\mathbf{y}'(k)$ を求め、

ここで $\mathbf{y}(k)=[\mathbf{r}^T(k+Q-1)\ \mathbf{r}^T(k+Q-2)\cdots\mathbf{r}^T(k)]^T$

$\mathbf{r}(k)=[r_1(k)\ r_2(k)\cdots r_M(k)]^T$

チャネル行列 $\mathbf{H}$ 又は参照信号を用いて、差分ベクトル $\mathbf{y}'(k)$ 内の残余干渉成分を除去する、n番目の送信機よりの送信信号の受信信号に対する適応フィルタ係数 $\mathbf{w}_n(k)$ を求め、

差分ベクトル $\mathbf{y}'(k)$ を上記適応フィルタ係数 $\mathbf{w}_n(k)$ によりフィルタ処理して、n番目の送信機よりの送信信号に対する干渉除去された受信信号として対数尤度比を得ることを特徴とするターボ受信方法。

【請求項2】 受信ベクトル $\mathbf{y}(k)$ 中の雑音成分の共分散行列をUとして、軟判定送信シンボル $b'_n(k)$、上記チャネル行列 $\mathbf{H}$ と、を用いて、上記適応フィルタ $\mathbf{w}_n(k)$ を

$$\mathbf{w}_n(k)=(\mathbf{H}\mathbf{G}(k)\mathbf{H}^H+U)^{-1}\mathbf{h}$$

ここで、

$\mathbf{G}(k)=\mathrm{diag}[\mathbf{D}(k+Q-1)\cdots\mathbf{D}(k)\cdots\mathbf{D}(k-Q+1)]$

$\mathbf{D}(k+q)=\mathrm{diag}[1-b'^2_1(k+q),\cdots,1-b'^2_n(k+q),\cdots,1-b'^2_1(k+q)]$ q=Q−1…−Q+1，q≠0で、

$=\mathrm{diag}[1-b'^2_1(k+q),\cdots,1,\cdots,1-b'^2_N(k+q)]$ q=0で、

【数2】

$$\mathbf{h}=\begin{bmatrix} H_{1,(Q-1)\cdot N+n} \\ H_{2,(Q-1)\cdot N+n} \\ \vdots \\ H_{M,(Q-1)\cdot N+n} \end{bmatrix}$$

$\mathbf{H}_{1,(Q-1)\cdot N+n}$ は上記行列 $\mathbf{H}$ の1行（Q−1）N+n列成分により算出することを特徴とする請求項1記載のターボ受信方法。

【請求項3】 2以上の整数N個の送信機からの信号を受信するターボ受信方法であって、

1以上の整数M個の受信信号 r_m と、既知信号とから、チャネル値 $h_{mn}(q)$ 及びチャネル行列 $\mathbf{H}$ を計算し、

ここでm=1，…，M、n=1，…，N、q=0，…，Q−1、Qは各送信電波のマルチパスの数

N個の事前情報 $\lambda_2[b_n(k)]$ から軟判定送信シンボル $b'_n(k)$ を求め、ここでkは離散的時刻、

チャネル値 $h_{mn}(q)$ と軟判定送信シンボル $b'_n(k)$ を用いて、n番目の送信機の送信信号に対する干渉成分 $\mathbf{H}\cdot\mathbf{B}'(k)$ を計算し、

ここで

【数3】

$$\mathbf{H}=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & \ddots & \\ 0 & & H(0) & \cdots H(Q-1) \end{bmatrix}$$

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix}$$

$\mathbf{B}'(k)=[\mathbf{b}'^T(k+Q-1)\cdots\mathbf{b}'^T(k)\cdots\mathbf{b}'^T(k-Q+1)]^T$

$\mathbf{b}'(k+q)=[b'_1(k+q)\ b'_2(k+q)\cdots b'_N(k+q)]^T$

$q=Q-1\cdots\cdots-Q+1$　$q\neq 0$で

$\mathbf{b}'(k)=[b'_1(k)\cdots f(b'_n(k))\cdots b'_N(k)]^T$

$q=0$で

$\mathbf{b}'(k)$の要素の$f(b'_n(k))$はｎ番目であり、$f(\ )$は$f(0)=0$、かつ$d\{f(b'_n(k))\}/d\{b'_n(k)\}\geq 0$を満たす$b'_n(k)$を変数とする関数、$[\ ]^T$は転置行列であり、

この干渉成分$\mathbf{H}\cdot\mathbf{B}'(k)$を受信ベクトル$\mathbf{y}(k)$から差し引き差分ベクトル$\mathbf{y}'(k)$を求め、

ここで$\mathbf{y}(k)=[\mathbf{r}^T(k+Q-1)\ \mathbf{r}^T(k+Q-2)\cdots\mathbf{r}^T(k)]^T$

$\mathbf{r}(k)=[r_1(k)\ r_2(k)\cdots r_M(k)]^T$

チャネル行列$\mathbf{H}$又は参照信号を用いて、差分ベクトル$\mathbf{y}'(k)$内の残余干渉成分を除去する、ｎ番目の送信機よりの送信信号の受信信号に対する適応フィルタ係数$\mathbf{w}_n(k)$を求め、

差分ベクトル$\mathbf{y}'(k)$を上記適応フィルタ係数$\mathbf{w}_n(k)$によりフィルタ処理して、ｎ番目の送信機よりの送信信号に対する干渉除去された受信信号として対数尤度比を得ることを特徴とするターボ受信方法。

【請求項４】　上記受信ベクトル$\mathbf{y}(k)$中の雑音成分の共分散行列をＵとして、軟判定送信シンボル$b'_n(k)$、上記チャネル行列$\mathbf{H}$を用いて、上記適応フィルタ$\mathbf{w}_n(k)$を

$$\mathbf{w}_n(k)=(\mathbf{H}\mathbf{G}(k)\mathbf{H}^H+U)^{-1}\mathbf{h}$$

ここで、

$$\mathbf{G}(k)=\mathrm{diag}[\mathbf{D}(k+Q-1)\cdots\mathbf{D}(k)\cdots\mathbf{D}(k-Q+1)]$$

$$\mathbf{D}(k+q)=\mathrm{diag}[1-b'^2_1(k+q),\cdots,1-b'^2_n(k+q),\cdots,1-b'^2_1(k+q)]\quad q=Q-1\cdots-Q+1,\ q\neq 0で、$$

$$=\mathrm{diag}[1-b'^2_1(k+q),\cdots,1-b'^2_{n-1}(k),1+2E[f(b'_n(k)]+E[f(b'_n(k)^2],1-b'^2_{n+1}(k),\cdots,1-b'^2_N(k+q)]\quad q=0で$$

$E[\ ]$は平均を表わす。

【数４】

$$\mathbf{h}=\begin{bmatrix}H_{1,(Q-1)\cdot N+n}\\ H_{2,(Q-1)\cdot N+n}\\ \vdots\\ H_{M,(Q-1)\cdot N+n}\end{bmatrix}$$

$\mathbf{H}_{1,(Q-1)\cdot N+n}$は上記行列$\mathbf{H}$の１行$(Q-1)N+n$列成分により算出することを特徴とする請求項３記載のターボ受信方法。

【請求項５】　上記適応フィルタ$\mathbf{w}_n(k)$の計算における逆行列演算を逆行列の補助定理を用いて行うことを特徴とする請求項２又は４に記載のターボ受信方法。

【請求項６】　受信ベクトル$\mathbf{y}(k)$内の雑音成分の共分散行列Ｕをガウス分布の分散値σ^2と単位行列から求まる$\sigma^2\mathbf{I}$とすることを特徴とする請求項１乃至５の何れかに記載のターボ受信方法。

【請求項７】　上記受信ベクトル$\mathbf{y}(k)$内の雑音成分の共分散行列Ｕを、上記受信ベクトル$\mathbf{y}(k)$、上記推定チャネル行列$\mathbf{H}$、を用い、

$\hat{U}=\Sigma_{k=0}^{Tr}(\mathbf{y}(k)-\hat{\mathbf{H}}\cdot\mathbf{B}(k))\cdot(\mathbf{y}(k)-\hat{\mathbf{H}}\cdot\mathbf{B}(k))^H$

$\mathbf{B}(k)=[\mathbf{b}^T(k+Q-1)\cdots\mathbf{b}^T(k)\cdots\mathbf{b}^T(k-Q+1)]^T$

$\mathbf{b}(k+q)=[b_1(k+q)\cdots b_N(k+q)]^T$

$(q=-Q+1\cdots Q-1)$

Ｔｒは参照信号の長さとすることを特徴とする請求項１乃至５の何れかに記載のターボ受信方法。

【請求項８】　上記$D(k+q)$を０と近似し、上記$D(k)$を$\mathrm{diag}[0,\cdots,1,\cdots,0]$で近似することを特徴とする請求項２乃至７の何れかに記載のターボ受信方法。

【請求項９】　２以上の整数Ｎ個の送信機からの信号を受信するターボ受信方法であって、

１以上の整数Ｍ個の受信信号r_mと、既知信号とから、チャネル値$h_{mn}(q)$及びチャネル行列$\mathbf{H}$を計算し、ここで、$m=1,\cdots,M$、$n=1,\cdots,N$、$q=0,\cdots,Q-1$、Ｑは各送信電波のマルチパスの数

Ｎ個の事前情報$\lambda_2[b_n(k)]$から軟判定送信シンボル$b'_n(k)$を求め、ここでｋは離散的時刻、

チャネル値$h_{mn}(q)$と軟判定送信シンボル$b'_n(k)$を用いて、ｎ番目の送信機の送信信号に対する干渉成分$\mathbf{H}\cdot\mathbf{B}'(k)$を計算し、

ここで

【数５】

$$H=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & \ddots & \\ 0 & & H(0) & \cdots H(Q-1) \end{bmatrix}$$

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix}$$

$\mathbf{B}'(k)=[\mathbf{b}'^{T}(k+Q-1)\cdots\mathbf{b}'^{T}(k)\cdots\mathbf{b}'^{T}(k-Q+1)]^{T}$

$\mathbf{b}'(k+q)=[b'_1(k+q)\ b'_2(k+q)\cdots b'_N(k+q)]^{T}$

$q=Q-1\cdots\cdots-Q+1$　　$q\neq0$で

$\mathbf{b}'(k)=[b'_1(k)\cdots0\cdots b'_N(k)]^{T}$

$q=0$で

$\mathbf{b}'(k)$の要素のゼロはｎ番目であり、$[\ ]^{T}$は転置行列であり、

この干渉成分$\mathbf{H}\cdot\mathbf{B}'(k)$を受信ベクトル$\mathbf{y}(k)$から差し引き差分ベクトル$\mathbf{y}'(k)$を求め、

ここで$\mathbf{y}(k)=[\mathbf{r}^{T}(k+Q-1)\ \mathbf{r}^{T}(k+Q-2)\cdots\mathbf{r}^{T}(k)]^{T}$

$\mathbf{r}(k)=[r_1(k)\ r_2(k)\cdots r_M(k)]^{T}$

受信ベクトル$\mathbf{y}(k)$内の雑音成分の共分散行列を、ガウス分布の分散σ^2と単位行列$\mathbf{I}$から求まる$\sigma^2\mathbf{I}$として、

【数６】

$$h=\begin{bmatrix} H_{1,(Q-1)\cdot N+n} \\ H_{2,(Q-1)\cdot N+n} \\ \vdots \\ H_{M\cdot Q,(Q-1)\cdot N+n} \end{bmatrix}$$

により決定した適応フィルタ係数$\mathbf{w}_n$により差分ベクトル$\mathbf{y}'(k)$をフィルタ処理して、ｎ番目の送信機よりの送信信号に対する干渉が除去された受信信号として対数尤度比を得ることを特徴とするターボ受信方法。

【請求項１０】　２以上の整数Ｎ個の送信機からの信号を受信するターボ受信方法であって、

１以上の整数Ｍ個の受信信号r_mと、既知信号とから、チャネル値$h_{mn}(q)$及びチャネル行列$\mathbf{H}$を計算し、ここで$m=1,\cdots,M$、$n=1,\cdots,N$、$q=0,\cdots,Q-1$、Ｑは各送信電波のマルチパスの数

Ｎ個の事前情報$\lambda_2[b_n(k)]$から軟判定送信シンボル$b'_n(k)$を求め、ここでｋは離散的時刻、

チャネル値$h_{mn}(q)$と軟判定送信シンボル$b'_n(k)$を用いて、ｎ番目の送信機の送信信号に対する干渉成分$\mathbf{H}\cdot\mathbf{B}'(k)$を計算し、

ここで

【数７】

$$H=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & \ddots & \\ 0 & & H(0) & \cdots H(Q-1) \end{bmatrix}$$

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix}$$

$\mathbf{B}'(k)=[\mathbf{b}'^{T}(k+Q-1)\cdots\mathbf{b}'^{T}(k)\cdots\mathbf{b}'^{T}(k-Q+1)]^{T}$

$\mathbf{b}'(k+q)=[b'_1(k+q)\ b'_2(k+q)\cdots b'_N(k+q)]^{T}$

$q=Q-1\cdots\cdots-Q+1$　　$q\neq0$で

$\mathbf{b}'(k)=[b'_1(k)\cdots f(b'_n(k))\cdots b'_N(k)]^{T}$

$q=0$で

$\mathbf{b}'(k)$の要素の$f(b'_n(k))$はｎ番目であり、$f(\ )$は$f(0)=0$、かつ$d\{f(b'_n(k))\}/d\{b'_n(k)\}\geq0$を満たす$b'_n(k)$を変数とする関数、$[\ ]^{T}$は転置行列であり、

この干渉成分$\mathbf{H}\cdot\mathbf{B}'(k)$を受信ベクトル$\mathbf{y}(k)$から差し引き差分ベクトル$\mathbf{y}'(k)$を求め、

ここで$\mathbf{y}(k)=[\mathbf{r}^{T}(k+Q-1)\ \mathbf{r}^{T}(k+Q-2)\cdots\mathbf{r}^{T}(k)]^{T}$

$\mathbf{r}(k)=[r_1(k)\ r_2(k)\cdots r_M(k)]^{T}$

受信ベクトル$\mathbf{y}(k)$内の雑音成分の共分散行列を、ガウス分布の分散σ^2と単位行列$\mathbf{I}$から求まる$\sigma^2\mathbf{I}$として、

【数８】

$$h=\begin{bmatrix} H_{1,(Q-1)\cdot N+n} \\ H_{2,(Q-1)\cdot N+n} \\ \vdots \\ H_{M\cdot Q,(Q-1)\cdot N+n} \end{bmatrix}$$

により決定した適応フィルタ係数$\mathbf{w}_n$により差分ベクトル$\mathbf{y}'(k)$をフィルタ処理して、ｎ番目の送信機よりの送信信号に対する干渉が除去された受信信号として対数尤度比を得ることを特徴とするターボ受信方法。

【請求項１１】　２以上の整数Ｎ個の送信機からの送信信号を受信するターボ受信方法であって、

１以上の整数Ｍ個の受信信号と既知信号とから受信信号

の伝送特性であるチャネル値を求め、
Ｎ個の事前情報から軟判定送信シンボルをそれぞれ推定し、
Ｎ個の送信信号をそれぞれ１乃至複数個の送信信号よりなるＬ個（Ｌ≦Ｎ）の送信信号群に分割し、その各送信信号群について、軟判定送信シンボル及びチャネル値よりなるチャネル行列を用いて、他の送信信号群からの干渉をそれぞれ除去したＬ個の等化信号と、その等化信号の伝送特性とそれぞれ対応する等化後のチャネル情報を求め、
これらＬ組の等化信号とそのチャネル情報の各組について、その等化信号群を受信信号とし、チャネル情報をチャネル値とし、その構成送信信号が複数個の場合は、その構成送信信号を更に１乃至複数個の送信信号よりなる複数の送信信号群に分割して軟判定送信シンボルを用いて、その送信信号群について、他の送信信号群からの干渉をそれぞれ除去した等化信号と等化後のチャネル情報を求め、構成送信信号が１個の場合はその等化信号とチャネル情報と軟判定送信シンボルを用いて、その送信信号自体のマルチパスによる干渉を除去し、
全ての等化信号の構成送信信号が１個になるまで上記分割、干渉除去及び等化後のチャネル情報の生成を繰り返し、最終的に各送信信号についてそれ自体のマルチパスによる干渉を除去した等化信号を求め、又は上記等化信号及びそのチャネル情報の組についてその等化信号の構成送信信号ごとにその送信信号相互間干渉及び自身の符号間干渉を除去した等化信号を求めることを特徴とするターボ受信方法。

【請求項１２】　上記各送信信号群について、軟判定送信シンボル及びチャネルを用いて、他の送信信号群からの干渉レプリカをそれぞれ生成し、受信信号から干渉レプリカをそれぞれ差引いてそれぞれ差分信号を求め、上記チャネル値と軟判定送信シンボルから干渉剰余成分除去用フィルタ特性及び上記等化後のチャネル情報を、各差分信号ごとに求め、その干渉剰余成分除去用フィルタ特性により対応する差分信号をフィルタ処理して、上記等化信号を得ることを特徴とする請求項１１記載のターボ受信方法。

【請求項１３】　上記受信信号 $r_1(k)$，…，$r_M(k)$ から受信ベクトル

$\mathbf{y}(k)=[\mathbf{r}^T(k+Q-1)\ \mathbf{r}^T(k+Q-2)\cdots\mathbf{r}^T(k)]^T$

$\mathbf{r}(k)=[r_1(k)\ r_2(k)\cdots r_M(k)]^T$

$[\ ]^T$ は転置行列を表わすを求め、
上記伝送特性をチャネル行列 $\mathbf{H}$ として

【数９】

$$H=\begin{bmatrix} H(0) & \cdots & H(Q-1) & & 0 \\ & \ddots & & \ddots & \\ 0 & & H(0) & \cdots & H(Q-1) \end{bmatrix}$$

$\mathbf{H}(q)=[\mathbf{h}_1(q)\cdots\mathbf{h}_N(q)]$

$\mathbf{h}_n(q)=[h_{1n}(q)\cdots h_{Mn}(q)]^T$

$m=1,\cdots,M$，$n=1,\cdots,N$，マルチパスの数をＱとし、$q=0,\cdots,Q-1$ であり、$h_{mn}(q)$ は受信信号 r_m に含まれる第ｎ送信機からのパスｑのチャネル値であり、を求め、
上記軟判定送信シンボルを $b'_n(k)$ とし、上記１つの送信信号群についてその構成を第１乃至第Ｕ送信信号、ここでＵはＮ＞Ｕ≧１なる整数であり、上記他の送信信号群よりの干渉レプリカを $\mathbf{H}\cdot\mathbf{B}'(k)$ により計算し、
ここで $\mathbf{B}'(k)=[\mathbf{b}'^T(k+Q-1)\cdots\mathbf{b}'^T(k)\cdots\mathbf{b}'^T(k-Q+1)]^T$

$\mathbf{b}'(k+q)=[b'_1(k+q)\ b'_2(k+q)\cdots b'_n(k+q)\cdots b'_N(k+q)]^T$：$q=Q-1,\cdots 1$ で

$\mathbf{b}'(k+q)=[0\cdots0\ \ b_{U+1}'(k+q)\cdots b'_N(k+q)]^T$：$q=0,\cdots,-Q+1$ で、

$\mathbf{b}'(k+q)$ 中の０の要素の数はＵ個であり、
この干渉レプリカ $\mathbf{H}\cdot\mathbf{B}'(k)$ を上記受信ベクトル $\mathbf{y}(k)$ から引算して上記差分ベクトル $\mathbf{y}'_g(k)$ を求めることを特徴とする請求項１２記載のターボ受信方法。

【請求項１４】　上記等化信号とそのチャネル情報に対し、更に干渉除去を行う際に、その等化信号が先に受けた干渉除去処理の際のマルチパスの数を小とすることを特徴とする請求項１１又は１２記載のターボ受信方法。

【請求項１５】　上記受信信号 $r_1(k)$，…，$r_M(k)$ から受信ベクトル

$\mathbf{y}(k)=[\mathbf{r}^T(k+Q-1)\ \mathbf{r}^T(k+Q-2)\cdots\mathbf{r}^T(k)]^T$

$\mathbf{r}(k)=[r_1(k)\ r_2(k)\cdots r_M(k)]^T$

$[\ ]^T$ は転置行列を表わすを求め、
上記伝送特性をチャネル行列 $\mathbf{H}$ として

【数１０】

$$H=\begin{bmatrix} H(0) & \cdots & H(Q-1) & & 0 \\ & \ddots & & \ddots & \\ 0 & & H(0) & \cdots & H(Q-1) \end{bmatrix}$$

$\mathbf{H}(q)=[\mathbf{h}_1(q)\cdots\mathbf{h}_N(q)]$

$\mathbf{h}_n(q)=[h_{1n}(q)\cdots h_{Mn}(q)]^T$

$m=1,\cdots,M$，$n=1,\cdots,N$，マルチパスの数をＱとし、$q=0,\cdots,Q-1$ であり、$h_{mn}(q)$ は受信信号 r_m に含まれる第ｎ送信機からのパスｑのチャネル値であり、を求め、
上記軟判定送信シンボルを $b'_n(k)$ とし、上記１つの送信信号群についてその構成を第１乃至第Ｕ送信信号とし、ここでＵはＮ＞Ｕ≧１なる整数であり、この送信信号群に対し干渉除去処理された等化信号に対する干渉除去処理におけるマルチパスの数を $Q'<Q$ とし、上記

他の送信信号群よりの干渉レプリカを $\mathbf{H}\cdot\mathbf{B}'(k)$ により計算し、
ここで
$\mathbf{B}'(k)=[\mathbf{b}'^T(k+Q-1)\cdots\mathbf{b}'^T(k)\cdots\mathbf{b}'^T(k-Q+1)]^T$
$\mathbf{b}'(k+q)=[b'_1(k+q)\ b'_2(k+q)\cdots b'_n(k+q)\cdots b'_N(k+q)]^T$: $q=Q-1,\cdots 1$ で
$\mathbf{b}'(k+q)=[0\cdots0\ \ b'_{u+1}(k+q)\cdots b'_N(k+q)]^T$: $q=0,\cdots,-Q'+1$
$\mathbf{b}'(k+q)$ 中の０の要素数はＵ個であり、
$\mathbf{b}'(k+q)=[b'_1(k+q)\cdots b'_n(k+q)\cdots b'_N(k+q)]^T$: $q=Q',\cdots,-Q+1$
この干渉レプリカ $\mathbf{H}\cdot\mathbf{B}'(k)$ を上記受信ベクトル $\mathbf{y}(k)$ から引算して差分ベクトル $\mathbf{y}'_g(k)$ を求ることを特徴とする請求項１４記載のターボ受信方法。

【請求項１６】 ターボ受信処理の２回目以後の繰り返し処理において、既知信号と前回の処理で得られた送信符号化シンボル硬判定出力とを参照信号とし、この参照信号と受信信号とを用いて、上記チャネル行列を計算することを特徴とする請求項１乃至１５の何れかに記載のターボ受信方法。

【請求項１７】 前回の処理で得られた送信符号化シンボル硬判定出力中の確からしさが所定値以上のものを参照信号として上記チャネル行列の計算に用いることを特徴とする請求項１６記載のターボ受信方法。

【請求項１８】 上記Ｎ個の事前情報 $\lambda_2[b_n(k)]$ は上記Ｎ個の送信機と対応したＮ個の復号器より得たものであり、上記ｎ番目の送信信号に対する干渉除去された受信信号としての対数尤度比を対応する復号器へ供給することを特徴とする請求項１乃至１７の何れかに記載のターボ受信方法。

【請求項１９】 上記Ｎ個の送信信号は、１つの情報系列をＮ個の並列の系列としてＮ個の送信機によりそれぞれ送信した信号であり、上記Ｎ個の事前情報 $\lambda_2[b_n(k)]$ は１個の復号器よりの事前情報 $\lambda_2[b(j)]$ を直列－並列変換したものであり、上記Ｎ個の送信信号に対する干渉除去された受信信号としてのＮ個の対数尤度比を並列－直列変換して上記復号器へ供給することを特徴とする請求項１乃至１７の何れかに記載のターボ受信方法。

【請求項２０】 ２以上の整数Ｎ個の送信機からの信号を受信するターボ受信機であって、
１以上の整数Ｍ個の受信信号 r_m を得る受信信号生成部と、ここで $m=1,\cdots,M$
各受信信号 r_m と既知信号の参照信号とが入力され、チャネル値 $h_{mn}(q)$ 及びチャネル行列 $\mathbf{H}$ を計算するチャネル推定器と、
ここで

【数１１】

$$\mathbf{H}=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ \cdot & \ddots & \ddots & \\ 0 & & H(0) & \cdots H(Q-1) \end{bmatrix}$$

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix}$$

$n=1,\cdots,N$
各受信信号 r_m が入力されて受信ベクトル
$\mathbf{y}(k)=[\mathbf{r}^T(k+Q-1)\ \ \mathbf{r}^T(k+Q-2)\cdots\mathbf{r}^T(k)]^T$
$\mathbf{r}(k)=[r_1(k)\ \ r_2(k)\cdots r_M(k)]^T$
ここでｋは離散的時刻、Ｑは各送信電波のマルチパスの数、$q=0,\cdots,Q-1$、$[\ \ ]^T$ は転置行列を表わす、を生成する受信ベクトル生成部と、
Ｎ個の事前情報が入力され、軟判定送信シンボル $b'_n(k)$ を生成する軟判定シンボル生成部と、
各軟判定送信シンボル $b'_1(k)$ ～ $b'_N(k)$ が入力され、ｎ番目の送信信号に対する干渉レプリカベクトル
$\mathbf{B}'(k)=[\mathbf{b}'^T(k+Q-1)\cdots\mathbf{b}'^T(k)\cdots\mathbf{b}'^T(k-Q+1)]^T$
$\mathbf{b}'(k+q)=[b'_1(k+q)\ b'_2(k+q)\cdots b'_N(k+q)]^T$
$q=Q-1,\cdots,-Q+1$, $q\neq0$ で
$\mathbf{b}'(k)=[b'_1(k)\cdots0\cdots b'_N(k)]^T$
$q=0$ で
$\mathbf{b}'(k)$ の要素のゼロはｎ番目、
を生成するレプリカベクトル生成部と、
チャネル行列 $\mathbf{H}$ と干渉レプリカベクトル $\mathbf{B}'(k)$ が入力され、ｎ番目の送信信号の受信信号に対する干渉成分 $\mathbf{H}\cdot\mathbf{B}'(k)$ を計算して出力するフィルタ処理部と、
干渉成分 $\mathbf{H}\cdot\mathbf{B}'(k)$ と受信ベクトル $\mathbf{y}(k)$ が入力され、差分ベクトル $\mathbf{y}'(k)=\mathbf{y}(k)-\mathbf{H}\cdot\mathbf{B}'(k)$ を出力する差演算部と、
チャネル行列 $\mathbf{H}$ 又は参照信号が入力され、差分ベクトル $\mathbf{y}'(k)$ 内の残余干渉成分を除去するｎ番目の送信機よりの送信信号の受信信号に対する適応フィルタ係数 $\mathbf{w}_n(k)$ を求めるフィルタ係数推定部と、
差分ベクトル $\mathbf{y}'(k)$ と上記適応フィルタ係数 $\mathbf{w}_n(k)$ が入力され、$\mathbf{y}'(k)$ に対しフィルタ処理して、ｎ番目の送信機よりの送信信号に対する干渉除去された受信信号として対数尤度比を得てｎ番目の復号器へ供給する適応フィルタ部と、を具備することを特徴とするターボ受信機。

【請求項２１】　２以上の整数Ｎ個の送信機からの信号を受信するターボ受信機であって、
１以上の整数Ｍ個の受信信号r_mを得る受信信号生成部と、ここでｍ＝１，…，Ｍ
Ｎ個の復号器と、
各受信信号r_mと、既知信号の参照信号とが入力され、チャネル値$h_{mn}(q)$及びチャネル行列$\mathbf{H}$を計算するチャネル推定器と、
ここで
【数１２】

$$H=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & & \ddots \\ 0 & & H(0) & \cdots H(Q-1) \end{bmatrix}$$

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix}$$

ｎ＝１，…，Ｎ
各受信信号r_mが入力されて受信ベクトル
$\mathbf{y}(k)=[\mathbf{r}^T(k+Q-1)\ \mathbf{r}^T(k+Q-2)\cdots\mathbf{r}^T(k)]^T$
$\mathbf{r}(k)=[r_1(k)\ \ r_2(k)\cdots r_M(k)]^T$
ここでｋは離散的時刻、Ｑは各送信電波のマルチパスの数、ｑ＝０，…，Ｑ－１、［　］^{T}は転置行列を表わす、を生成する受信ベクトル生成部と、
Ｎ個の事前情報が入力され、軟判定送信シンボル$b'_n(k)$（ｎ＝１，…，Ｎ）を生成する軟判定シンボル生成部と、
各軟判定送信シンボル$b'_1(k)$～$b'_N(k)$が入力され、ｎ番目の送信機よりの送信信号に対する干渉レプリカベクトル
$\mathbf{B}'(k)=[\mathbf{b}'^T(k+Q-1)\cdots\mathbf{b}'^T(k)\cdots\mathbf{b}'^T(k-Q+1)]^T$
$\mathbf{b}'(k+q)=[b'_1(k+q)\ b'_2(k+q)\cdots b'_N(k+q)]^T$
ｑ＝Ｑ－１，…，－Ｑ＋１，　ｑ≠０で
$\mathbf{b}'(k)=[b'_1(k)\cdots f(b'_n(k))\cdots b'_N(k)]^T$
ｑ＝０で
$\mathbf{b}'(k)$の要素の$f(b'_n(k))$はｎ番目、$f(\ )$は$f(0)=0$、かつ$d\{f(b'_n(k))\}/d\{b'_n(k)\}\geq 0$を満す$b'_n(k)$を変数とする関数であり、を生成するレプリカベクトル生成部と、
チャネル行列$\mathbf{H}$と干渉レプリカベクトル$\mathbf{B}'(k)$が入力され、ｎ番目の送信機よりの送信信号の受信信号に対する干渉成分$\mathbf{H}\cdot\mathbf{B}'(k)$を計算して出力するフィルタ処理部と、
干渉成分$\mathbf{H}\cdot\mathbf{B}'(k)$と受信ベクトル$\mathbf{y}(k)$が入力され、差分ベクトル$\mathbf{y}'(k)=\mathbf{y}(k)-\mathbf{H}\cdot\mathbf{B}'(k)$を出力する差演算部と、
チャネル行列$\mathbf{H}$又は参照信号が入力され、差分ベクトル$\mathbf{y}'(k)$内の残余干渉成分を除去するｎ番目の送信機よりの送信信号の受信信号に対する適応フィルタ係数$\mathbf{w}_n(k)$を求めるフィルタ係数推定部と、
差分ベクトル$\mathbf{y}'(k)$と上記適応フィルタ係数$\mathbf{w}_n(k)$が入力され、$\mathbf{y}'(k)$に対しフィルタ処理して、ｎ番目の送信機よりの送信信号に対する干渉除去された受信信号として対数尤度比を得てｎ番目の復号器へ供給する適応フィルタ部と、を具備することを特徴とするターボ受信機。
【請求項２２】　２以上の整数Ｎ個の送信機から送信信号を受信するターボ受信機であって、
１以上の整数Ｍ個の受信信号を生成する受信信号生成部と、
上記Ｍ個の受信信号と既知信号の参照信号が入力され、その伝送特性であるチャネル値を推定するチャネル推定器と、
上記Ｍ個の受信信号と、上記チャネル値Ｎ個の事前情報とが入力され、１乃至複数の上記送信機の送信信号ごとに、他の送信機の送信信号による干渉成分を除去した等化信号と、その等化信号と対応する等化後のチャネル情報との複数組を出力する前段等化器と、
上記前段等化器より上記等化信号とそのチャネル情報の組と、その等化信号の構成送信信号と対応する事前情報とがそれぞれ入力され、その等化信号から、構成送信信号のそれぞれについてそのマルチパスによる符号間干渉又はこれとその構成信号中の他の送信信号との相互干渉とを除去して対数尤度比を出力する複数の後段等化器と、を具備するターボ受信機。
【請求項２３】　２以上の整数Ｎ個の送信機から送信信号を受信するターボ受信機であって、
１以上の整数Ｍ個の受信信号を生成する受信信号生成部と、
上記Ｍ個の受信信号と既知信号の参照信号が入力され、その伝送特性であるチャネル値を推定するチャネル推定器と、
上記Ｍ個の受信信号と、上記チャネル値とＮ個の事前情報とが入力され、１乃至複数の上記送信機の送信信号ごとに、他の送信機の送信信号による干渉成分を除去した等化信号と、その等化信号と対応する等化後のチャネル情報との複数組を出力する前段等化器と、
上記前段等化器より上記等化信号とそのチャネル情報の組とその等化信号を構成する複数の送信信号と対応する事前情報とが入力され、その等化信号の複数の構成送信信号中の１乃至複数の送信信号ごとに、その構成送信信号中の他の他送信信号による干渉成分を除去した等化信

号と、その等化信号と対応する等化後のチャネル情報との複数組を出力する複数の後段等化器を具備するターボ受信機。

【請求項２４】 復号器よりの硬判定送信シンボルが、これにより更新記憶される前回シンボル記憶部と、ターボ受信処理の２回目以後の繰り返し処理において、前回シンボル記憶部から硬判定送信シンボルを読み出し、参照信号としてチャネル推定器へ供給する手段とを備えることを特徴とする請求項２０乃至２３の何れかに記載のターボ受信機。

【請求項２５】 軟判定送信シンボルが入力され、しきい値と比較する比較部と、その比較部の出力により制御され、硬判定送信シンボル中のその軟判定送信シンボルがしきい値以上のものを前回シンボル記憶部へ格納する選択部とを備える請求項２４記載のターボ受信機。

【請求項２６】 上記出力されたＮ個の対数尤度比がそれぞれ供給されるＮ個の復号器を備え、上記Ｎ個の復号器の出力から上記Ｎ個の事前情報が得られることを特徴とする請求項２０乃至２５の何れかに記載のターボ受信機。

【請求項２７】 上記Ｎ個の送信信号は１つの情報系列をＮ個の並列の系列としてＮ個の送信機よりそれぞれ送信された信号であり、上記出力されるＮ個の対数尤度比を直列系列に変換する並列－直列変換部と、上記直列系列の対数尤度比が入力される復号器と、上記復号器よりの事前情報をＮ個の並列系列に変換して上記Ｎ個の事前情報を得る直列－並列変換部とを備えることを特徴とする請求項２０乃至２５の何れかに記載のターボ受信機。

【請求項２８】 受信信号の伝送路特性としてのチャネル値を、受信信号と参照信号としての既知信号とから推定し、その推定したチャネル値を用いて受信信号を処理し、その処理した信号に対し復号処理を行い、同一受信信号に対し上記推定したチャネル値を利用した処理と復号処理とを繰り返し行う受信方法において、

復号された硬判定情報シンボルの確からしさを、その軟判定情報シンボルの値から決定し、確からしさが所定値以上の硬判定情報シンボルをも次回のチャネル推定の参照信号に用いることを特徴とするターボ受信方法。

【請求項２９】 受信ベクトル $\mathbf{y}$（ｋ）内の雑音成分の共分散行列として、上記繰り返し毎に、σ^2 $\mathbf{I}$（σ^2 はガウス分布の分散値、$\mathbf{I}$ は単位行列）を計算する過程を含むことを特徴とする請求項２８記載のターボ受信方法。

【請求項３０】 受信信号ベクトル $\mathbf{y}$（ｋ）内の雑音成分の共分散行列Ｕを、上記繰り返し毎に、推定されたチャネル行列 $\mathbf{H}$＾と受信信号ベクトル $\mathbf{y}$（ｋ）を用いて、

$$U^{\wedge}=\Sigma_{k=0}{}^{Tr}(\mathbf{y}(k)-\mathbf{H}^{\wedge}\cdot\mathbf{B}(k))\cdot(\mathbf{y}(k)-\mathbf{H}^{\wedge}\cdot\mathbf{B}(k))^{H}$$

$$\mathbf{B}(k)=[\mathbf{b}^{T}(k+Q-1)\cdots\mathbf{b}^{T}(k)\cdots\mathbf{b}^{T}(k-Q+1)]^{T}$$

$$\mathbf{b}(k+q)=[b_1(k+q)\cdots b_N(k+q)]^{T}\quad(q=-Q+1\cdots Q-1)$$

b_1（ｋ＋ｑ）からb_N（ｋ＋ｑ）は、上記既知信号及び上記確からしさが所定値以上の硬判定情報シンボルよりなる参照信号、Ｔｒはその参照信号長であり、を計算する過程を含むことを特徴とする請求項２８記載のターボ受信方法。

【請求項３１】 上記推定したチャネル値を利用した処理と復号処理との繰り返しは、上記推定したチャネル値により線形等化フィルタを決定し、その線形等化フィルタにより受信信号を処理し、その処理した信号を復号することの繰り返しであることを特徴とする請求項２８～３０の何れかに記載のターボ受信方法。

【請求項３２】 上記推定したチャネル値を利用した処理と復号処理との繰り返しは、上記推定したチャネル値により、レーク合成処理部内で、各シンボルが伝送路で受けた位相回転を補償するレーク合成処理を行い、そのレーク合成処理された信号をターボデコーダにより復号することの繰り返しである、ことを特徴とする請求項２８～３０の何れかに記載のターボ受信方法。

【請求項３３】 上記推定したチャネル値を利用した処理と復号処理との繰り返しは、アダプティブアレーアンテナ受信部に対し、上記推定したチャネル値によりアンテナ指向特性を決定する重みを設定し、アダプティブアレーアンテナ受信部の出力をターボデコーダにより復号することの繰り返しであることを特徴とする請求項２８～３０の何れかに記載のターボ受信方法。

【請求項３４】 上記アダプティブアレーアンテナ受信部の出力をレーク合成処理部内で、各シンボルが伝送路で受けた位相回転を上記推定したチャネル値により補償するレーク合成処理を行い、そのレーク合成処理された信号を上記ターボデコーダへ供給することを特徴とする請求項３３記載のターボ受信方法。

【請求項３５】 受信信号の伝送路特性であるチャネル値を、受信信号と参照信号としての既知信号とから推定し、その推定したチャネル値を用いて受信信号を処理し、その処理した信号に対し復号処理を行い、同一受信信号に対し上記推定したチャネル値を利用した処理と復号処理とを繰り返し行う受信機において、

復号された硬判定情報シンボルの確からしさが所定値以上か否かを、その軟判定情報シンボルの値がしきい値以上か否かにより決定する手段と、

その確からしいと決定された硬判定情報シンボルにより記憶内容が更新記憶される前回シンボル記憶部を備え、次回のチャネル推定の参照信号として前回シンボル記憶部の記憶内容が用いられることを特徴とするターボ受信機。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】この発明は、例えば移動通信に適用され、干渉にもとづく波形歪を、ターボ符号技術を応用した繰り返し等化を行うターボ受信方法、及びその受信機に関する。

【０００２】

【従来の技術】移動体通信事業の課題は限られた周波数上でいかに高品質で多数のユーザを所有できるシステムを構築するかということにある。このような課題を解決する手段として多入力多出力（Multi-Input Multi-Output：ＭＩＭＯ）システムがある。このシステム構成は図３０Ａに示されているように複数の送信機Ｓ１～ＳＮから同時刻、同周波数上でシンボルc_1（ｉ）～c_N（ｉ）をそれぞれ送信し、これらの送信信号を、複数のアンテナ＃１～＃Ｍを備えるＭＩＭＯ受信機で受信し、ＭＩＭＯ受信機は受信信号を処理し、各送信機Ｓ１～ＳＮの送信シンボルc_1（ｉ）～c_N（ｉ）を推定してc_1^（ｉ）～c_N^（ｉ）として出力端子Ｏｕｔ１～ＯｕｔＮに別々に出力する。

【０００３】現在までのところＭＩＭＯシステムにおけるＭＩＭＯ受信機の具体的な構成法に関する検討は十分に行われていない。ＭＩＭＯシステムにおけるＭＩＭＯ受信機の構成をＭＬＳＥ（最尤推定）規範に基づいて行う場合は、送信機の数をＮ、各送信機の送信電波がＭＩＭＯ受信機に到達するマルチパスの数をＱとすれば、ＭＩＭＯ受信機の計算量は$2^{(Q-1)N}$ の桁になってしまい、送信機数Ｎ、マルチパス数Ｑの増加に伴いその計算量は莫大なものとなる。またシングルユーザの情報を複数の並列信号として送信されたものを受信する場合に、各並列信号を分離するにはマルチパス数の増加に伴い多くの計算量を必要とする。そこでこの発明は計算効率のよい複数系列信号のターボ受信方法を提案するものであるが、まずこの発明の元となる既存のシングルユーザ（送信機１台）、つまり１系列送信信号に対するターボ受信機について説明する。

【０００４】シングルユーザ用ターボ受信機

この場合の送信機、受信機の構成例を図３１に示す。送信機１０では情報系列ｃ（ｉ）の符号化が符号化器１１で行われ、その符号化出力がインタリーバ１２でインタリーブ（並べ替え）された後、変調器１３で搬送波信号を変調し、その変調出力が送信される。この送信信号は伝送路（マルチパスの各チャネル）を通じて受信機２０に受信される。受信機２０では軟入力軟出力（ＳＩＳＯ:Ｓｉｎｇｌｅ-Ｉｎｐｕｔ-Ｓｉｎｇｌｅ-Ｏｕｔｐｕｔ）等化器２１により遅延波の等化が行われる。この等化器２１の入力は一般に受信信号がベースバンドに変換され、そのベースバンドの受信信号が、送信信号の情報系列のシンボル信号の周波数の１倍以上の周波数でサンプリングされてディジタル信号に変換され、ディジタル信号の受信信号として等化器２１へ入力される。

【０００５】シングルユーザの場合図３０ＡでＮ＝１にあたり、各受信アンテナ＃ｍ（ｍ＝１，２，…，Ｍ）における受信出力は、

$$r_m(k)=\Sigma_{q=0}^{Q-1}\ h_m(q)\cdot b(k-q)+v_m(k) \qquad (1)$$

と表すことができる。ｍはアンテナインデックス、ｈはチャネル値（伝送路インパルス応答：伝送路特性）、ｂ（ｋ－ｑ＋１）はユーザ（送信機１）の送信シンボル、v_m（ｋ）は受信機２０の内部の熱雑音である。そして全てのアンテナ＃１～＃Ｍからの出力を式（２）のベクトルとして表わし、式（３）

$$\mathbf{r}(k)=[r_1(k)\ r_2(k)\cdots r_M(k)]^T \qquad (2)$$

$$=\Sigma_{q=0}^{Q-1}\ \mathbf{H}(q)\cdot\mathbf{b}(k-q+1)+\mathbf{v}(k) \qquad (3)$$

を定義する。ここで、

$$\mathbf{v}(k)=[v_1(k)\ v_2(k)\cdots v_M(k)]^T \qquad (4)$$

$$\mathbf{H}(q)=[h_1(q)\cdots h_M(q)]^T \qquad (5)$$

である。また［　］^{T} は転置行列を表わす。次にマルチパス（チャネル）の数Ｑを考慮して以下のベクトル及び行列を定義する。

【０００６】

$$\mathbf{y}(k)\equiv[\mathbf{r}^T(k+Q-1)\ \mathbf{r}^T(k+Q-2)\cdots\mathbf{r}^T(k)]^T \qquad (6)$$

$$\equiv\mathbf{H}\cdot\mathbf{b}(k)+\mathbf{n}(k) \qquad (7)$$

ここで、

【０００７】

【数１３】

$$\mathbf{H}=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & \ddots & \\ 0 & & H(0) & \cdots H(Q-1)\end{bmatrix} \qquad (8)$$

【０００８】ただし、

$$\mathbf{b}(k-q)=[b(k+Q-1)\ b(k+Q-2)\cdots b(k-Q+1)]^T \qquad (9)$$

$$\mathbf{n}(k)=[\mathbf{v}^T(k+Q-1)\ \mathbf{v}^T(k+Q-2)\cdots\mathbf{v}^T(k)]^T$$

である。上で定義した $\mathbf{r}$（ｋ）が等化器２１に入力され、このＳＩＳＯ等化器２１は線形等化器であって、その等化出力として各符号化ビット｛ｂ（ｉ）｝が＋１である確率と－１である確率の対数尤度比 Λ_1（ＬＬＲ：Log-LikelihoodRatio）が導出される。

【０００９】

【数１４】

$$\Lambda_1[b(k)] = \log\frac{\Pr[b(k)=+1\,|\,\mathbf{y}(k)]}{\Pr[b(k)=-1\,|\,\mathbf{y}(k)]} \qquad (11)$$

$$\equiv \lambda_1[b(k)] + \lambda_2^p[b(k)] \qquad (12)$$

【００１０】である。ここで λ_1［ｂ（ｋ）］は後続の復号器２４に送られる外部情報、$\lambda_2{}^p$［ｂ（ｋ）］は等化器２１に与えられる事前情報である。対数尤度比 Λ_1［ｂ（ｋ）］は事前情報 λ_2［ｂ（ｋ）］が減算器２２で減算され、更にデインタリーバ２３を介してＳＩＳＯチャネル復号器２４へ供給される。この復号器２４は対数尤度比 Λ_2、

【００１１】

【数１５】

$$\Lambda_2[b(i)] = \log\frac{\Pr[b(i)=+1\,|\,\lambda_1[b(i)],i=0,\cdots,B-1]}{\Pr[b(i)=-1\,|\,\lambda_1[b(i)],i=0,\cdots,B-1]} \qquad (13)$$

Ｂ：フレーム長

$$\equiv \lambda_2[b(i)] + \lambda_1^p[b(i)] \qquad (14)$$

【００１２】を算出する。ここで λ_2［ｂ（ｉ）］は繰り返しの際に等化器２１に $\lambda_2{}^p$［ｂ（ｋ）］として与えられる外部情報であり、λ_1［ｂ（ｋ）］が復号器２４に事前情報 $\lambda_1{}^p$［ｂ（ｉ）］として与えられる。Λ_2［ｂ（ｉ）］は減算器２５で λ_1［ｂ（ｉ）］が減算され、インタリーバ２６を介して等化器２１及び減算器２２へ供給される。このようにして繰り返し等化、復号が行われて誤り率の向上が達成される。次に前段の等化器２１の詳細として受信ベクトル $\mathbf{y}$（ｋ）に施す線形フィルタ特性の算定について述べる。等化器２１の事前情報 $\lambda_2{}^p$［ｂ（ｋ）］を用いて軟判定シンボル推定値

$$b'(k) = \tanh[\lambda_2{}^p[b(k)]/2] \qquad (15)$$

を算出する。そして、この推定値とチャネル行列 $\mathbf{H}$ を用いて干渉成分、つまり干渉成分のレプリカ $\mathbf{H}\cdot\mathbf{b}'(k)$ を再生し、受信信号から引き算する。つまり

$$\mathbf{y}'(k) \equiv \mathbf{y}(k) - \mathbf{H}\cdot\mathbf{b}'(k) \qquad (16)$$

$$= \mathbf{H}\cdot(\mathbf{b}(k) - \mathbf{b}'(k)) + \mathbf{n}(k) \qquad (17)$$

ここで、

$$\mathbf{b}'(k) = [b'(k+Q-1)\cdots 0\cdots b'(k-Q+1)]^T \qquad (18)$$

を計算する。干渉成分のレプリカ $\mathbf{H}\cdot\mathbf{b}'(k)$ は正確なレプリカに必ずしもなっていないから、式（１６）により干渉成分を完全に除去できない。そこで干渉成分の残りを消す線形フィルタ係数 $\mathbf{w}(k)$ を以下のＭＭＳＥ（最小平均２乗誤差）規範で求める。

【００１３】

$$\mathbf{w}(k) = \arg\min \|\mathbf{w}^H(k)\cdot\mathbf{y}'(k) - b(k)\|^2 \qquad (19)$$

Hは共役転置を表わし、‖　‖はノルムを表わす。式（１９）を最小とする $\mathbf{w}$（ｋ）を求める。以下の $\mathbf{w}$（ｋ）の導出は文献：Daryl Reynolds and Xiaodong Wang, “LowComplexity Turbo-Equalization for Diversity Channels” (http:/ee.tamu.edu/reynolds/) に記載されている。この手法の主な達成事項として計算量の大幅削減がある。従来のＭＬＳＥ型ターボの計算量は 2^{Q-1} のオーダに比例していたのに対し、この手法は Q^3 のオーダで抑えられている。なお $\mathbf{w}^H(k)\cdot\mathbf{y}'(k)$ は等化器２１の出力であって、これから λ_1［ｂ（ｋ）］が計算されてデインタリーバ２３を介して復号器２４へ供給され、復号演算が行われる。

【００１４】等化器２１において等化処理を行うには、式（１）中のチャネル値（伝送路インパルス応答）ｈを推定する必要がある。このチャネル値の推定を以下ではチャネル推定と記す。チャネル推定は、１フレーム内の先頭部に送られて来るユニークワードなどの既知のトレーニング系列の受信信号と、記憶してあるトレーニング系列とを用いて行われている。チャネル推定の精度が悪いと、等化器２１での等化処理が正しく行われない。チャネル推定の精度を高くするには１フレーム内のトレーニング系列の占める割合を大きくすればよいが、そのようにすると本来のデータに対する伝送効率が低下する。従って、１フレーム内のトレーニング系列の占める割合を小さくし、かつチャネル推定精度を向上させることが望まれる。

【００１５】このことはＭＩＭＯを含む多系列送信信号に対する受信機に限らず、レーク（ＲＡＫＥ）受信機や

アダプティブアレーアンテナを用いた受信機においても繰り返し復号処理により復号結果の確からしさを向上させる受信機では、そのチャネル推定においては同様な問題がある。

【００１６】

【発明が解決しようとする課題】上記のターボ受信機は以下の課題を持っている。

・シングルユーザ（一台の送信機）、つまり１系列の送信信号のみの対応である。

・干渉成分を再生する際にチャネル値（行列Ｈ）が必要であり、実装の際にはこれを推定する必要がある。

その推定誤差が繰り返し等化の効果を劣化させてしまう。

【００１７】この発明の目的はこの２点を補うべく以下にこの受信用をマルチユーザ、やシングルユーザ並列送信などの複数の送信系列信号に対する受信機に拡張したターボ受信方法及びその受信機を提供することにある。またこの発明の他の目的は、受信信号のチャネル値を、受信信号と参照信号としての既知信号とから推定し、その推定したチャネル値を用いて受信信号を処理し、その処理した信号に対し、復号処理を行い、同一受信信号に対し、上記推定したチャネル値を利用した処理と復号処理とを繰り返し行う受信方法において、比較的短かい既知信号によりチャネル推定を精度よく行うことができるターボ受信方法及びその受信機を提供することにある。

【００１８】

【課題を解決するための手段】この第１発明はＮ系列（Ｎは２以上の整数）の送信信号を受信するターボ受信方法であって、Ｍ個の受信信号 r_m（ｍ＝１，…，Ｍ）と、Ｎ系列の既知信号とから、チャネル値 $h_{mn}(q)$（ｎ＝１，…，Ｎ）を計算し、復号により得られたＮ系列の事前情報 λ_2［b_n（ｋ）］に基づき軟判定送信シンボル b'_n（ｋ）を求め、チャネル値 $h_{mn}(q)$ と軟判定送信シンボル b'_n（ｋ）を用いて、ｎ系列目の送信信号自身が作る符号間干渉とｎ系列目の送信信号以外の送信信号によって作られる干渉成分 $\mathbf{H}\cdot\mathbf{B}'(k)$ を計算し、ここで

【００１９】

【数１６】

$$\mathbf{H}=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & & \ddots & \\ 0 & & H(0) & & \cdots H(Q-1) \end{bmatrix}$$

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix}$$

【００２０】$\mathbf{B}'(k)=[\mathbf{b}'^T(k+Q-1)\cdots\mathbf{b}'^T(k)\cdots\mathbf{b}'^T(k-Q+1)]^T$

$\mathbf{b}'(k+q)=[b'_1(k+q)\ b'_2(k+q)\cdots b'_N(k+q)]^T$

ｑ＝Ｑ－１……－Ｑ＋１　ｑ≠０で

$\mathbf{b}'(k)=[b'_1(k)\cdots 0\cdots b'_N(k)]^T$

ｑ＝０で

（$\mathbf{b}'(k)$ の要素のゼロはｎ番目）、Ｑは各送信信号電波のマルチパスの数、ｑ＝０，…，Ｑ－１、$[\,]^T$ は転置行列を表わす。

【００２１】この符号間干渉 $\mathbf{H}\cdot\mathbf{B}'(k)$ を受信ベクトル $\mathbf{y}(k)$ から差し引き差分ベクトル $\mathbf{y}'(k)$ を求める。

ここで $\mathbf{y}(k)=[\mathbf{r}^T(k+Q-1)\ \mathbf{r}^T(k+Q-2)\cdots\mathbf{r}^T(k)]^T$

$\mathbf{r}(k)=[r_1(k)\ r_2(k)\cdots\mathbf{r}_M(k)]^T$

チャネル行列 $\mathbf{H}$ 又は参照信号を用いて差分ベクトル $\mathbf{y}'(k)$ 内の残余干渉成分を除去するための、ｎ系列目の送信信号の受信信号に対する適応フィルタ係数 $\mathbf{w}_n(k)$ を求め、差分ベクトル $\mathbf{y}'(k)$ を上記適応フィルタ係数 $\mathbf{w}_n(k)$ によりフィルタ処理して、ｎ系列目の送信信号に対する干渉除去された受信信号としてｎ系列の対数尤度比を得る。これらＮ系列の対数尤度比を用いて復号する。

【００２２】第２発明によれば、第１発明において、ｑ＝０の場合に、

$\mathbf{b}'(k)=[b'_1(k)\cdots f(b'_n(k))\cdots b'_N(k)]^T$

$\mathbf{b}'(k)$ の要素の $f(b'_n(k))$ はｎ番目であり、ｆ（　）は $f(0)=0$、かつ $d\{f(b'_n(k))\}/d\{b'_n(k)\}\geq 0$ を満たす $b'_n(k)$ を変数とする関数とすることを特徴とする。第３発明によれば、等化処理を複数段階に分けて行い、後段程、等化出力の系列の数を少なくする。

【００２３】この第４発明によれば受信信号のチャネル値を、受信信号と参照信号としての既知信号とから推定し、その推定したチャネル値を用いて受信信号を処理し、その処理した信号に対し復号処理を行い、同一受信信号に対し、上記推定したチャネル値を利用した処理と復号処理とを繰り返し行うターボ受信方法において、復号された硬判定情報シンボルの確からしさを、その軟判定情報シンボルの値から決定し、その確からしさが所定値以上の硬判定情報シンボルをも次回のチャネル推定の参照信号に用いる。

【００２４】

【発明の実施の形態】第１発明（１）

図１にこの発明が適用されるＭＩＭＯシステムの構成例を示す。送信側のＮ個の送信機Ｓ１…ＳＮのそれぞれにおいて情報系列 c_1（ｉ）…c_N（ｉ）がそれぞれ符号器１１－１，…，１１－Ｎで符号化され、これら符号化出力はインタリーバ１２－１，…，１２－Ｎを通じて変

調器１３－１，…，１３－Ｎに変調信号として供給され、これら変調信号により搬送波信号が変調されて信号b_1（ｋ），…，b_N（ｋ）として送信される。つまり送信機Ｓ１，…，ＳＮからの送信信号b_1（ｋ），…，b_N（ｋ）がＮ系列の送信信号の場合である。

【００２５】伝送路（チャネル）を通じて多出力受信機に受信された受信信号 $\mathbf{r}$（ｋ）は多出力等化器３１に入力され、受信機に受信された信号はベースバンド信号に変換され、そのベースバンド信号は例えばそのシンボル周期の１／２の周期でサンプリングされてディジタル信号に変換されそのディジタル信号として等化器３１に入力される。またこのディジタル信号は１以上の整数Ｍ個とされる。例えばＭ個のアンテナよりの受信信号がＭ個のディジタル信号の受信信号とされる。等化器３１からＮ個の対数尤度比Λ_1［b_1（ｋ）］，…，Λ_1［b_N（ｋ）］が出力される。Λ_1［b_1（ｋ）］，…，Λ_1［b_N（ｋ）］はそれぞれ事前情報λ_1［b_1（ｋ）］，…，λ_1［b_N（ｋ）］が減算器２２－１，…，２２－Ｎでそれぞれ減算され、デインタリーバ２３－１，…，２３－Ｎを通じて軟入力軟出力（ＳＩＳＯ）復号器（チャネル復号器）２４－１，…，２４－Ｎにそれぞれ入力されて復号され、復号器２４-１，…，２４－Ｎから復号情報系列c'_1（ｉ），…，c'_N（ｉ）が出力されると共に対数尤度比Λ_2［b_1（ｉ）］，…，Λ_2［b_N（ｉ）］がそれぞれ出力される。Λ_2［b_1（ｉ）］，…，Λ_2［b_N（ｉ）］は減算器２５－１，…，２５－Ｎによりλ_1［b_1（ｉ）］，…，λ_1［b_N（ｉ）］がそれぞれ減算され、更に、インタリーバ２６－１，…，２６－Ｎをそれぞれ通じてλ_2［b_1（ｋ）］，…，λ_2［b_N（ｋ）］として多出力等化器３１及び減算器２２－１，…，２２－Ｎにそれぞれ供給される。

【００２６】マルチユーザ（複数送信機）からの受信信号r_m（ｋ）（ｍ＝１，…，Ｍ）は、等化器３１の入力として、

$$r_m(k)=\sum_{q=0}^{Q-1}\sum_{n=1}^{N}h_{mn}(q)\cdot b_n(k-q)+v_m(k) \qquad (20)$$

と複数ユーザ分足し合わせたものとなる。ｑ＝０，…，Ｑ－１，Ｑは各送信電波のマルチパスの数、そしてシングルユーザの場合と同じ手順でベクトル $\mathbf{y}$（ｋ）を定義すると、

$$\mathbf{y}(k)\equiv[\mathbf{r}^T(k+Q-1)\ \mathbf{r}^T(k+Q-2)\cdots\mathbf{r}^T(k)]^T \qquad (21)$$

$$=\mathbf{H}\cdot\mathbf{B}(k)+\mathbf{n}(k) \qquad (22)$$

ここで、$\mathbf{r}(k)=[r_1(k)\cdots r_M(k)]^T$

【００２７】

【数１７】

$$\mathbf{H}=\begin{bmatrix}H(0) & \cdots H(Q-1) & & 0\\ & \ddots & \ddots & \\ 0 & & H(0) & \cdots H(Q-1)\end{bmatrix} \qquad (23)$$

【００２８】

【数１８】

$$H(q)=\begin{bmatrix}h_{11}(q) & \cdots & h_{1N}(q)\\ \vdots & \ddots & \vdots\\ h_{M1}(q) & \cdots & h_{MN}(q)\end{bmatrix} \qquad (24)$$

ただし、

【００２９】

$$\mathbf{B}(k)=[\mathbf{b}^T(k+Q-1)\cdots\mathbf{b}^T(k)\cdots\mathbf{b}^T(k-Q+1)]^T \qquad (25)$$

$$\mathbf{b}(k+q)=[b_1(k+q)\ b_2(k+q)\cdots b_N(k+q)]^T$$

$$q=Q-1,\ Q-2,\ \cdots,\ -Q+1 \qquad (26)$$

となる。次に干渉除去ステップにおいて、今第ｎ番目のユーザ（送信機）からの信号が所望であると仮定する。この例では全ユーザ（送信機）よりの信号の軟判定シンボル推定値とチャネル行列（伝送路インパルス応答値行列）$\mathbf{H}$を用いて、第ｎ番目以外のユーザの信号による干渉と第ｎ番目のユーザの信号自身が作る干渉との合成したもの、つまり干渉レプリカ$\mathbf{H}\cdot\mathbf{B}'$（ｋ）を再生して以下のように、$\mathbf{y}$（ｋ）からこの干渉レプリカを引算して差分ベクトル$\mathbf{y}'$（ｋ）を生成する。

【００３０】

$$\mathbf{y}'(k)\equiv\mathbf{y}(k)-\mathbf{H}\cdot\mathbf{B}'(k) \qquad (27)$$

$$=\mathbf{H}\cdot(\mathbf{B}(k)-\mathbf{B}'(k))+\mathbf{n}(k) \qquad (28)$$

ここで、

$$\mathbf{B}'(k)=[\mathbf{b}'^T(k+Q-1)\cdots\mathbf{b}'^T(k)\cdots\mathbf{b}'^T(k-Q+1)]^T \qquad (29)$$

そして、

$$\mathbf{b}'(k+q)=[b'_1(k+q)\ b'_2(k+q)\cdots b'_N(k+q)]^T : q=Q-1,\ \cdots,\ -Q+1,\ q\neq 0 \qquad (30)$$

$$\mathbf{b}'(k)=[b'_1(k)\cdots 0\cdots b'_N(k)]^T : q=0 \quad (31)$$

$\mathbf{b}'(k)$の要素中の０はｎ番目である。$b'_n(k)$は式（１５）と同様に$b'_n(k)=\tan h[\lambda_2[b_n(k)]/2]$を計算して求めた軟判定送信シンボル推定値である。ベクトル$\mathbf{B}'(k)$は干渉シンボルのレプリカベクトルである。

【００３１】次に干渉成分の残り、つまり干渉成分レプリカ$\mathbf{H}\cdot\mathbf{B}'(k)$の不完全性に基づく干渉剰余と、第ｎ番目自身の信号が作る干渉成分とを消すための第ｎ番目のユーザ用のフィルタ係数$\mathbf{w}_n(k)$を以下の式（３２）を最小とする$\mathbf{w}_n(k)$をＭＭＳＥ（最小平均２乗誤差）規範で求める。

$$\mathbf{w}_n(k)=\arg\min\|\mathbf{w}_n{}^H(k)\cdot\mathbf{y}'(k)-b_n(k)\|^2 \quad (32)$$

以下の操作はシングルユーザの場合と同一である。つまり求めた$\mathbf{w}_n(k)$を用いて$\mathbf{w}_n{}^H(k)\cdot\mathbf{y}'(k)$を計算し、その計算結果をデインタリーバ２３－ｎを介して$\lambda_1[b_n(i)]$として、復号器２４－ｎに入力して復号演算が行われる。

【００３２】ユーザ１からＮまで以上の方法で受信信号r_mに対しフィルタ（線形等化）処理を求めていく。その結果等化器３１の出力数はＮとなり、これら出力は各々の復号器２４－１，…，２４－Ｎにより復号される。以上がシングルユーザ用ターボ受信機のマルチユーザ（ＭＩＭＯ）用への拡張である。以上の説明から、多出力等化器３１の機能構成例は図２に示すようになる。Ｍ個の受信信号$r_m(k)$は受信ベクトル生成部３１１により受信ベクトル$\mathbf{y}(k)$が生成され、各ユーザごとの等化部３１２－１～３１３－Ｎへ供給される。またチャネル推定器２８において計算されたチャネル行列$\mathbf{H}$も等化部３１２－１～３１２－Ｎへ供給される。各チャネル復号器２４－ｎからの事前情報$\lambda_2[b_n(k)]$が軟判定シンボル推定部３１３に入力され、それぞれ軟判定送信シンボル推定値$b'_n(k)=\tanh[\lambda_2[b_n(k)]/2]$が計算される。等化部３１２－１～３１２－Ｎ内の機能構成と処理は同一であり、等化部３１２－１で代表して説明する。

【００３３】さらに軟判定送信シンボルの推定値$b'_1(k)$～$b'_N(k)$が、干渉レプリカベクトル生成部３１４－１に供給され、式（２９）～（３１）により干渉レプリカベクトル$\mathbf{B}'_1(k)$が生成され、このベクトル$\mathbf{B}'_1(k)$はフィルタ処理部３１５－１でチャネル行列$\mathbf{H}$によりフィルタ処理され、その結果の干渉レプリカ成分$\mathbf{H}\cdot\mathbf{B}'_1(k)$が、差演算部３１６－１で受信ベクトル$\mathbf{y}_1(k)$から差し引かれ、差分ベクトル$\mathbf{y}'_1(k)$が生成される。

【００３４】フィルタ係数推定部３１７－１に少くともチャネル行列$\mathbf{H}$、又は後述するように参照信号が入力され、前記干渉成分の残りを除去するためのフィルタ係数$\mathbf{w}_1(k)$が求められる。この例ではチャネル推定器２８よりのチャネル行列$\mathbf{H}$と雑音成分の共分散σ^2と、軟判定シンボル生成部３１３－１からの軟判定送信シンボル$b'_1(k)$～$b'_N(k)$がフィルタ係数推定部３１７－１に入力され、式（３２）を最小とするフィルタ係数$\mathbf{w}_1(k)$が最小平均２乗誤差規範で求められる。このフィルタ係数$\mathbf{w}_1(k)$を求める具体的処理は後で述べる。適応フィルタ処理部３１８－１で差分ベクトル$\mathbf{y}'_1(k)$がフィルタ係数$\mathbf{w}_1(k)$により処理され、ユーザ１からの送信信号に対する受信信号の等化出力として$\Lambda_1[b_1(k)]$が出力される。

【００３５】また前述したこの発明の実施例の多入力多出力ターボ受信方法の処理手順を図３に示す。ステップＳ１で受信信号ｒ（ｋ）と各トレーニング信号$b_n(k)$からチャネル値$h_{mn}(q)$及び雑音成分の共分散σ^2を計算し、ステップＳ２でそのチャネル値$h_{mn}(q)$からチャネル行列$\mathbf{H}$を計算し、ステップＳ３でターボ受信処理における前回の処理で得た各事前情報$\lambda_2[b_n(k)]$から軟判定送信シンボル推定値$b'_n(k)=\tanh(\lambda_2[b_n(k)]/2)$を計算する。

【００３６】ステップＳ４で受信信号ｒ（ｋ）から受信ベクトル$\mathbf{y}(k)$を生成し、ステップＳ５で各軟判定送信シンボル推定値$b'_n(k)$を用いて式（２９）～（３１）により干渉レプリカベクトル$\mathbf{B}'_n(k)$を生成し、ステップＳ６でｎ番目送信機よりの受信信号に対する干渉成分レプリカ$\mathbf{H}\cdot\mathbf{B}'_n(k)$を計算する。ステップＳ７で受信ベクトル$\mathbf{y}(k)$から干渉成分レプリカ$\mathbf{H}\cdot\mathbf{B}'_n(k)$を差し引き、差分ベクトル$\mathbf{y}'_n(k)$を求める。ステップＳ８でチャネル行列$\mathbf{H}$と、軟判定送信シンボル$b'_1(k)$～$b'_N(k)$と、雑音成分の共分散$\sigma^2$とにより、ｎ番目送信機よりの受信信号中の残余干渉を除去するためのフィルタの係数$\mathbf{w}_n(k)$を、式（３２）を最小とする最小平均２乗誤差規範で求める。

【００３７】ステップＳ９で差分ベクトル$\mathbf{y}'_n(k)$に対しフィルタ係数$\mathbf{w}_n(k)$によるフィルタ処理を行って対数尤度比$\Lambda_1[b_n(k)]$を得る。ステップＳ１０で$\Lambda_1[b_n(k)]$から事前情報$\lambda_2[b_n(k)]$を減算した後、デインタリーブを施し、更に復号を行って対数尤度比$\Lambda_2[b_n(k)]$を出力する。このステップＳ４～Ｓ１０の処理をｎ＝１～Ｎについて同時に又は順次に行う。その後、ステップＳ１１で復号回数、つまりターボ受信処理回数が所定数になったかを調べ、所定数になってなければ、ステップＳ１２で対数尤度比$\Lambda_2[b_n(k)]$から外部情報$\lambda_1[b_n(k)]$を減算し、その結果をインタリーブして事前

情報λ_2 ［b_n （ｋ）］を求めてステップＳ３に戻る。ステップＳ１１で復号が所定回数の場合はステップＳ１３でその時の復号結果を出力する。

$$r_m(k)=\Sigma_{q=0}^{Q-1}\ \Sigma_{n=1}^{N}\ h_{mn}(q)\cdot b_n(k-q)+v_m(k)\qquad(33)$$

チャネル推定部２８は式（３３）中のチャネル値（伝送路インパルス応答）のh_{mn}（ｑ）の値とノイズv_m（ｋ）の平均電力（≡σ^2）を求める。通常送信側は図４Ａに示すように受信機で既知のユニークワード（トレーニング信号）を各送信フレームの始めに挿入し、受信機はそのユニークワード（既知信号）をトレーニング系列としてＲＬＳ（再帰的最小２乗法）などを用いてチャネル値h_{mn}（ｑ）を推定していく。各チャネル復号器２４－１，…，２４－Ｎから、その対数尤度比Λ_2 ［b_1 （ｉ）］，…，Λ_2 ［b_N （ｉ）］のそれぞれについて、正であれば＋１を負であれば－１をそれぞれ復号符号信号（送信符号化シンボル硬判定値）b_1＾（ｉ），…，b_N＾（ｉ）として出力し、これらb_1＾（ｉ），…，b_N＾（ｉ）はインタリーバ２７－１，…，２７－Ｎを通じて繰り返しチャネル推定器２８に入力される。チャネル推定器２８には受信信号　ｒ　（ｋ）が入力されると共にユニークワード記憶部２９からユニークワードが参照信号として入力される。チャネル推定器２８はこれら入力された信号に基づき、式（３３）の各h_{mn}（ｑ）とσ^2の各値を最小２乗法により推定する。この推定は伝送路のインパルス応答を推定して受信信号を適応フィルタにより適応的に等化する場合のインパルス応答の推定と同様の手法で行うことができる。

【００３９】このようにトレーニング系列を用いるのは通常用いられる手法であるが、正味の伝送速度を上げるには１フレーム内のユニークワードの占める割合を小さくする必要があり、そうすればチャネル推定の誤差は増大する。そしてその誤差が上記の繰り返し等化の特性を劣化させてしまう。そこでチャネル値の繰り返し推定を次のようにするとよい。その概念を図４Ｂに示す。これは同一受信信号の繰り返し等化処理、つまりターボ受信処理の繰り返し処理の各段階でチャネル値も繰り返し推定していこうというものである。つまり１回目においてはユニークワードの後の情報シンボル系列に対しては、ユニークワードのみを参照信号として用いてチャネル値を推定し、その推定したチャネル値を用いて受信信号を等化し送信シンボルを推定するが、２回目以降の等化処理の前に、そのユニークワードを参照信号として用いてチャネル推定を行い、かつ前回の復号処理で得られたシンボル推定値（硬判定値）も参照信号として用いてフレーム内全体でチャネル推定を行う。この場合、全ての硬判定値を用いるのではなく、確からしいと判断された硬判定値のみを参照信号として用いるとよい。硬判定は復号器２４－ｎからの対数尤度比Λ_2 ［b_n （ｉ）］を用いてこれが正なら＋１、負なら－１とすることによって行われる。その際その対数尤度比Λ_2 ［b_n （ｉ）］の絶対値が大きいほどその硬判定値は確からしいと言える。例えば、対数尤度０．３を１と判定した時の１よりも、対数尤度５を１と判定したときの１の方が確からしい。そこで以下にしきい値を用いて確からしい硬判定値b_n （ｉ）を選定し、それを用いて繰り返しチャネル推定を行う方法を説明する。

【００３８】次にチャネル推定部２８について述べる。各受信信号r_m（ｋ）は次式で表わせる。

【００４０】まず復号器２４－ｎよりの対数尤度比Λ_2 ［b_n （ｉ）］を用いて、シンボルの軟判定値b'_n （ｉ）を、

b'_n （ｉ）＝tan ｈ［Λ_2 ［b_n （ｉ）］／2］

として求める。この操作は対数尤度値を１に規格化し絶対値が１を超えることはないようにするためである。次に予めしきい値（０と１の間）を用意しておき、その軟判定値b'_n （ｉ）の絶対値がそのしきい値よりも大きいものに対してその硬判定値ｂ＾$_n$ （ｉ）を保存しておき、これを繰り返しチャネル推定に用いる。例えばしきい値を０．９に設定すると軟判定値b'_n （ｉ）のうち絶対値が０．９以上の硬判定値ｂ＾$_n$ （ｉ）のみが選別される。しきい値が０．９と高いため選別された硬判定値ｂ＾$_n$ （ｉ）の確からしさは高いと考えられるから、これらを利用して行う繰り返しチャネル推定の精度は上がると考えられるが、その分、選別されるシンボル数が減少するため繰り返しチャネル推定精度は下がるとも考えられる。つまり最適なしきい値を０と１の間で選定する必要がある。補足として仮にしきい値を１と設定した場合、選別される硬判定値ｂ＾$_n$ （ｉ）はないため繰り返しチャネル推定は行われないということになる。そこで後で述べるが、しきい値は０．２～０．８程度に設定して行う。

【００４１】従って１回目の情報シンボル系列に対する送信シンボル推定値（硬判定値）b_1＾（ｉ），…，b_N＾（ｉ）中のしきい値により確からしいと判断されたシンボル値をインタリーバ２７－１，…，２７－Ｎの出力から前回送信シンボル推定値として前回シンボル記憶部３２に記憶しておき、受信信号　ｒ　（ｋ）の２回目の繰り返し等化復号処理においては（受信信号　ｒ　（ｋ）は記憶部に記憶してある）、まずユニークワードを用いてチャネル推定を行い、更に情報シンボル系列に対して、前回シンボル記憶部３２から、推定送信シンボル硬判定推定値ｂ＾$_1$ （ｉ），…，ｂ＾$_N$ （ｉ）中の確からしいと判定されたシンボル値を読み出してチャネル推定器２８に入力して、チャネル推定を行い、つまりフレーム内全体でのチャネル推定を行い、その推定値h_{mn}（ｑ）とσ^2 を用いて、受信信号　ｒ　（ｋ）に対する

等化、復号（送信シンボル推定）を行う。この際にその推定した送信シンボル中のしきい値により確からしいと判定されたシンボル値で前回シンボル記憶部３２の記憶内容を更新しておく。以下同様にして、等化、復号の繰り返しの際におけるチャネル推定はユニークワードを用いる推定と、前回の推定送信シンボル中の確からしいと判定されたものを用いる推定とによりフレーム内全体でチャネル推定を行う。その推定チャネルを用いて等化、復号（送信シンボル推定）を行い、また前回シンボル記憶部３２の更新を行う。なおこの前回シンボル記憶部３２には復号器からの送信シンボル硬判定値 $\hat{b}_1$（ｉ），…，$\hat{b}_N$（ｉ）中のしきい値により確からしいと判定されたシンボル値を前回シンボル記憶部３２に直接格納更新し、この前回シンボル記憶部３２の記憶シンボル値を利用する場合にインタリーバ２７－１，…，２７－Ｎを通してチャネル推定器２８へ入力するようにしてもよい。

【００４２】このようにすることによって繰り返しにより、チャネル推定の誤差が減少し、シンボル推定の精度が向上し、ターボ等化におけるチャネル推定誤差による特性劣化の問題を改善することができる。このように確からしいシンボル硬判定値を用いて情報シンボル系列においてチャネル推定を行う場合には、各復号器２４－ｎに図５に示す機能構成が付加される。対数尤度比 Λ_2［b_n（ｉ）］が軟判定値推定部２４１に入力され、b'_n(ｉ)＝ｔａｎｈ（Λ_2［b_n（ｉ）］）が計算され、送信シンボル軟判定値 b'_n（ｉ）が推定され、この値 b'_n（ｉ）が比較部２４２でしきい値設定部２４３からのしきい値Ｔｈと比較され、b'_n（ｉ）がＴｈ以上で１、Ｔｈより小で０が出力される。一方対数尤度比 Λ_2［b_n（ｉ）］が硬判定部２４４に入力され、Λ_2［b_n（ｉ）］が正なら＋１、負なら－１とされたシンボル硬判定値 $\hat{b}_n$（ｉ）が出力され、このシンボル硬判定値 $\hat{b}_n$（ｉ）は、対応するシンボル軟判定値がしきい値以上であればゲート２４５が開とされて出力され、図１中のインタリーバ２７－ｎを通じて前回シンボル記憶部３２に供給され、記憶中の前記シンボルが更新される。

【００４３】また確からしいシンボル硬判定値をも利用したチャネル推定の手順は図６に示すようになる。まずステップＳ１で受信信号ｒ（ｋ）とユニークワードとによるチャネル推定を行い、ステップＳ２で復号処理が１回目か否かを調べ、１回目であれば、ステップＳ３でその推定したチャネル値 h_{mn}（ｑ）を用いて等化、復号処理、つまり図３中のステップＳ３～Ｓ１０の処理を行う。ステップＳ４で対数尤度比 Λ_2［b_n（ｉ）］に対し、送信シンボル硬判定処理を行い、硬判定値 $\hat{b}_n$（ｉ）を求め、ステップＳ５で対数尤度比 Λ_2［b_n（ｉ）］に対し、b'_n（ｉ）＝ｔａｎｈ（Λ_2［b_n（ｉ）］／２）を計算して送信シンボル軟判定値 b'_n（ｉ）を推定する。ステップＳ６でシンボル軟判定値 b'_n（ｉ）がしきい値Ｔｈ以上か否かにより、対応シンボル硬判定値 $\hat{b}_n$（ｉ）の確からしいものを決定し、ステップＳ７でその確からしいシンボル硬判定値により、前回シンボル記憶部３２内の記憶内容を更新する。次にステップＳ８で復号回数が所定値であるかを調べ、所定値になっていなければ、ステップＳ１へ戻る。正確には図３中のステップＳ１２を経て図３中のステップＳ１に戻る。

【００４４】ステップＳ２で復号処理が１回でないと判定されると、ステップＳ９で前回シンボル記憶部３２から前回の記憶シンボル、つまり確からしい硬判定シンボルを読み出し、これと受信信号ｒ（ｋ）の情報シンボル系列とを用いてチャネル推定を行ってステップＳ３に移る。以上においては、２回目以後の処理においても、ユニークワードも参照信号として初期状態からチャネル推定をしたが、２回目以後は参照信号として確らしい硬判定シンボルのみを用いてもよい。この場合は図６中に破線で示すように、ステップＳ１′で１回目の処理かを調べ、１回目の処理であれば、ステップＳ２′でユニークワードを参照信号としてこれと、受信信号とによりチャネル値の推定を行い、ステップＳ３′でその推定チャネル値と、その推定に用いた各パラメータの値を記憶部に記憶した後、ステップＳ３の等化、復号処理へ移る。

【００４５】ステップＳ１′で１回目でなければ、チャネル推定処理に先立ち、ステップＳ４′で先に記憶したチャネル推定値と各種処理パラメータを設定してステップＳ９へ移る。所で式（３２）の解は次式となる。

$$\mathbf{w}_n(k)=(\mathbf{H}\,\mathbf{G}(k)\,\mathbf{H}^H+\sigma^2\,\mathbf{I})^{-1}\cdot\mathbf{h} \qquad (34)$$

$\mathbf{I}$ は単位行列、σ^2 は受信機の内部雑音電力（雑音成分の共分散）であり、$\sigma^2\,\mathbf{I}$ は雑音成分の共分散行列、$\mathbf{G}$（ｋ）はチャネル推定２乗誤差に対応する。

【００４６】

$$\mathbf{G}(k)\equiv E\left[(\mathbf{B}(k)-\mathbf{B}'(k))\cdot(\mathbf{B}(k)-\mathbf{B}'(k))^H\right] =\mathrm{diag}\left[\mathbf{D}(k+Q-1),\ \cdots,\ \mathbf{D}(k),\ \cdots,\ \mathbf{D}(k-Q+1)\right] \qquad (35)$$

Ｅ［］は平均を、diagは対角行列（対角線の要素以外の要素はゼロ）を表わす。また

$$\mathbf{D}(k+q)=\mathrm{diag}\left[1-b'^2_1(k+q),\ \cdots,\ 1-b'^2_n(k+b),\ \cdots,\ 1-b'^2_N(k+q)\right] \qquad (36)$$

ｑ＝Ｑ－１，Ｑ－２，…，－Ｑ＋１，ｑ≠０ ｑ＝０の時は

$$\mathbf{D}(k)=\mathrm{diag}\left[1-b'^2_1(k),\ \cdots,\ 1,\ \cdots,\ 1-b'^2_N(k)\right]$$

（３７）

ベクトル$\mathbf{D}$（ｋ）中の１はｎ番目の要素（ｎ番目のユーザの送信信号を所望の信号としている）である。

【００４７】

【数１９】

$$\mathbf{h}=\begin{bmatrix} H_{1,(Q-1)\cdot N+n} \\ H_{2,(Q-1)\cdot N+n} \\ \vdots \\ H_{M\cdot Q,(Q-1)\cdot N+n} \end{bmatrix} \qquad (38)$$

【００４８】つまり$\mathbf{h}$は式（２３）の$\mathbf{H}$の（Ｑ－１）・Ｎ＋ｎ列目の全要素からなる。図２に示したように多出力等化器３１のフィルタ係数推定部３１７－１では、チャネル推定器２８で推定されたチャネル行列$\mathbf{H}$及び雑音電力σ^2と、軟判定シンボル生成部３１３－１よりの軟判定送信シンボル$b'_1(k)\sim b'_N(k)$とが入力されて、残余干渉除去フィルタ係数$\mathbf{w}_n(k)$が式（３４）～（３８）により演算される。式（３４）は逆行列演算を行うことになるが、この演算は逆行列の補助定理（Matrix　Inversion Lemma）を用いることにより演算量を削減することができる。つまり式（３６）及び（３７）の各b'^2の部分を全て１に近似すると、

$$\mathbf{D}(k+q)=\mathrm{diag}[0,\cdots,0]=0 \quad (q\neq 0) \qquad (39)$$

$$\mathbf{D}(k)=\mathrm{diag}[0,\cdots,1,\cdots,0] \qquad (40)$$

つまり、$\mathbf{D}$（ｋ）の要素中のｎ行ｎ列の要素のみが１で、他の全ての要素は０となる。これら式（３９），（４０）で決まる式（３５）の誤差行列$\mathbf{G}$（ｋ）を式（３４）に代入すると、

$$\mathbf{w}_n(k)=(\mathbf{h}\cdot\mathbf{h}^H+\sigma^2\,\mathbf{I})^{-1}\cdot\mathbf{h} \qquad (41)$$

となる。$\mathbf{h}$は式（３８）で定義されたもの。

【００４９】この近似により、$\mathbf{w}_n(k)$はｋに依存しないため、離散的時刻ｋ毎の逆行列計算が不要となり、計算量が削減される。この式（４１）に対し、逆行列の補助定理を適用する。この逆行列の補助定理はＡ，Ｂを（Ｍ，Ｍ）の正方行列、Ｃを（Ｍ，Ｎ）行列、Ｄを（Ｎ，Ｎ）の正方行列とし、$A=B^{-1}+CD^{-1}C^H$で表される場合、Ａの逆行列は

$$A^{-1}=B-BC(D+C^H BBC)^{-1}C^H B \qquad (42)$$

で与えられる。式（４１）中の逆行列演算の部分にこの定理を適用すると、

$\mathbf{h}(k)\cdot\mathbf{h}(k)^H+\sigma^2\,\mathbf{I}=B^{-1}+CD^{-1}C^H$

$\mathbf{h}(k)\cdot\mathbf{h}(k)^H=CD^{-1}C^H$，$\sigma^2\,\mathbf{I}=B^{-1}$，$\mathbf{h}(k)=C$

$\mathbf{I}=D^{-1}$，$\mathbf{h}(k)^H=C^H$

となり、これを用いて式（４２）を計算すれば式（４１）中の逆行列演算が求まる。なお式（４２）中にも逆行列演算$(D+C^H BBC)^{-1}$が含まれるが、この逆行列はスカラとなるから簡単に計算することができる。

【００５０】つまりこの場合は、

$$\mathbf{w}_n(k)=1/(\sigma^2+\mathbf{h}^H\cdot\mathbf{h})\,\mathbf{h} \qquad (41\text{-}1)$$

となる。この式の右辺の１／（　）はスカラー、即ち一定数となるため１としてもよい。よって$\mathbf{w}_n(k)=\mathbf{h}$と置けるから、$\mathbf{h}$のみで$\mathbf{w}$（ｋ）が決定される。図２中のフィルタ係数推定部３１７－１には、破線で示すように、チャネル推定器２８からチャネル行列$\mathbf{H}$中の式（３８）で示される$\mathbf{h}$のみを入力すればよい。

【００５１】なお、式（３９）、式（４０）による近似は逆行列の補助定理を用いる場合に限らず、この近似により式（３４）の計算量を少くすることができる。特にこの近似を行い、かつ逆行列の補助定理を用いれば更に演算量を減少でき、またその際に雑音成分の共分散行列を$\sigma^2\,\mathbf{I}$とすると、式（４１－１）に示すように$\mathbf{w}_n(k)=\mathbf{h}$で近似でき、共分散行列に無関係となり、更に計算が簡略化される。

第２発明（誤り訂正反映）

式（２７）に示した受信ベクトル$\mathbf{y}$（ｋ）から$\mathbf{H}\cdot\mathbf{B}'$（ｋ）を減算する等化処理では、検出する信号$b_n(k)$以外の信号の送信シンボル軟判定値は誤り訂正復号結果が反映されているが、検出する信号$b_n(k)$に関する誤り訂正復号結果が反映されていない。そこで、以下のように処理をすることが好ましい。

【００５２】式（２９）中のb'（ｋ）、つまり式（３１）を次式に変更する。

$$\mathbf{b}'(k)=[b'_1(k)\ \ b'_2(k)\cdots\ b'_{n-1}(k)\ \ f(b'_n(k))\ \ b'_{n+1}(k)\cdots\ b'_N(k)] \qquad (43)$$

ただし、$f(b'_n(k))$は$b'_n(k)$を入力とする任意の関数このようにすることにより、検出する信号$b_n(k)$に関しても誤り訂正復号結果を反映させることが可能となる。つまり$b'_n(k)=0$とすることなく$b'_n(k)$に応じた適当な値を加算することにより、例えば、雑音や干渉信号に埋ずもれた検出する信号を強調することになって、$b_n(k)$を正しく検出することができる。

【００５３】$f(b'_n(k))$については、$b'_n(k)$の符号は$b'_n(k)$に対応するシンボルの硬

判定結果に関係し、また$b'_n(k)$の絶対値が大きいほど$b'_n(k)$に対応する硬判定シンボルの信頼性が大きいという性質から以下の条件を満たす必要がある。$b'_n(k)=0$、つまり硬判定シンボルの信頼性が０の場合はこの関数ｆの値も０である。即ち

$$f(0)=0 \tag{44}$$

である。また$b'_n(k)$の値が大きければ関数ｆの値も大きな値となる。即ち

$$d\{f(b'_n(k))\}/d\{b'_n(k)\}\geqq 0 \tag{45}$$

である。このような$f(b'_n(k))$の例としては、

$$f(b'_n(k))=\alpha\times b'_n(k) \tag{46}$$

$$f(b'_n(k))=\alpha\times b'_n(k)^2 \tag{47}$$

が挙げられる。例えば式（４６）を用いてαを定数とすれば式（４３）を簡単に実現できる。ここでαは$0<\alpha<0.6$である。αを０．６より大きくすると逆にＢＥＲ（誤り率）特性が劣化してしまい、正しい復号結果が得られなくなる。また、αを復号結果の信頼度に応じて可変することも考えられる。例えば復号処理の繰り返し毎にαを設定する。この場合、通常は復号処理の繰り返し回数が多くなるほど復号結果の信頼度が上がるため、復号処理の繰り返し回数に応じてαの値を大きくすれば良い。あるいは、復号処理の繰り返しごとに復号されたフレーム全体の信頼度を判定し、その判定に基づいてαの値を決定すればよい。復号されたフレームの信頼度を判定する方法として、例えば復号結果を１回前の繰り返し復号時の復号結果と比較し、前回の復号時から変化した硬判定シンボル数をカウントする方法が考えられる。すなわち、変化した硬判定シンボル数が多い場合には信頼度は低いと判定し、変化した硬判定シンボル数が少ない場合には信頼度が高いと判定すればよい。

【００５４】また、このような$b'_n(k)$の変更に伴い、ＭＭＳＥ（最小平均２乗誤差）フィルタの係数$\mathbf{w}_n(k)$を求める際に用いる式（３５）を以下のように変更することが望ましい。

$$\mathbf{G}(k)=E[(\mathbf{B}(k)-\mathbf{B}'(k))\cdot(\mathbf{B}(k)-\mathbf{B}'(k))^H]$$
$$=\mathrm{diag}[\mathbf{D}(k+Q-1),\cdots,\mathbf{D}(k),\cdots,\mathbf{D}(k-Q+1)]$$

ここで式（２９）、式（３１）より

【００５５】

【数２０】

$$B'(k)=\begin{bmatrix} b'(k+Q-1) \\ b'(k+Q-2) \\ \vdots \\ b'(k) \\ \vdots \\ b'(k-Q+1) \end{bmatrix} \qquad b'(k)=\begin{bmatrix} b'_1(k) \\ b'_2(k) \\ \vdots \\ -f(b'_n(k)) \\ \vdots \\ b'_N(k) \end{bmatrix}$$

【００５６】とする。$\mathbf{D}(k)$のｎ行ｎ列の要素は

$$E[(b_n(k)+f(b'_n(k)))\cdot(b_n(k)+f(b'_n(k)))]^*$$

［　］＊は複素共役を表わす。この式はＢＰＳＫ変調の場合は次式となる。

$$E[b_n(k)^2+2b_n(k)f(b'_n(k))+f(b'_n(k))^2]=E[b_n^2(k)]+2E[b_n(k)f(b'_n(k)]+E[f(b'_n(k)^2]$$

この第１項の平均値は１となる。また$b_n(k)$を$b'(k)$で近似すると式（３７）は以下のようになる。

【００５７】

$$\mathbf{D}(k)=\mathrm{diag}[1-b'^2_1(k)\quad 1-b'^2_2(k)\cdots 1-b'^2_{n-1}(k)\quad 1+2E[f(b'_n(k)b'_n(k)]+E[f(b'_n(k)^2]\quad 1-b'^2_{n+1}(k)\cdots 1-b'^2_1(k)] \tag{48}$$

例えば、$f(b'_n(k))$を式（４６）とした場合には、D（ｋ）は下記のようになる。

$$\mathbf{D}(k)=\mathrm{diag}[1-b'^2_1(k)\quad 1-b'^2_2(k)\cdots 1-b'^2_{n-1}(k)\quad 1+(2\alpha+\alpha^2)b'^2_n(k)\quad 1-b'^2_{n+1}(k)\cdots 1-b'^2_1(k)] \tag{49}$$

このように検出する信号に誤り訂正復号結果を反映させる場合に適応フィルタ係数$\mathbf{w}_n(k)$を推定する機能

構成例を、検出する信号として第１番目の送信機からの送信信号b_1（ｋ）とした場合を図７Ａに示す。軟判定送信シンボルb'_1（ｋ）が関数演算部３３１－１に入力され、関数演算ｆ（b'_1（ｋ））が演算される。またＮ個の復号器からの軟判定送信シンボルb'_1（ｋ）～b'_N（ｋ）とｆ（b'_1（ｋ））が誤差行列生成部３３２－１に入力され、式（３５）、式（３６）及び式（４８）により誤差行列$\mathbf{G}$（ｋ）が演算生成される。この誤差行列$\mathbf{G}$（ｋ）と、推定チャネル行列$\mathbf{H}$及び雑音電力σ^2とがフィルタ係数生成部３３３－１に入力され、ここで式（３４）が計算され、適応フィルタ係数$\mathbf{w}_n$（ｋ）が推定される。この場合は干渉レプリカベクトル生成部３１４－１にもｆ（b'_n（ｋ））が入力され、式（３０）と式（４３）から式（２９）の干渉レプリカベクトル$\mathbf{B}'$（ｋ）が生成される。フィルタ係数$\mathbf{w}_n$（ｋ）により差分ベクトル$\mathbf{y}'$（ｋ）が適応フィルタ部３１８－１でフィルタ処理されて対数尤度比Λ_1［b_1（ｋ）］が得られる。なお図２中のフィルタ係数推定部３１７－１の場合は図７Ａ中の関数演算部３３１－１が省略され、軟判定送信シンボルb'_1（ｋ）～b'_N（ｋ）のみが誤差行列生成部３３２－１に入力され、式（３４）が演算されることになる。

【００５８】図３中において、ステップＳ４で干渉レプリカベクトル$\mathbf{B}'$（ｋ）を生成し、更にステップＳ５～Ｓ７を処理し、ステップＳ８におけるフィルタ係数$\mathbf{w}_n$（ｋ）を求めるが、このステップＳ８の処理において式（３４）を演算する場合は、図７Ｂに示すように、ステップＳ８－２で軟判定送信シンボルb'_1（ｋ）～b'_N（ｋ）を用いて、式（３５）～（３７）を演算して誤差行列$\mathbf{G}$（ｋ）を生成し、ステップＳ８－３で誤差行列$\mathbf{G}$（ｋ）と推定チャネル行列$\mathbf{H}$及び雑音電力σ^2を用いて式（３４）の演算により適応フィルタ係数$\mathbf{w}_n$（ｋ）を求める。

【００５９】前述のように検出した信号に誤り訂正復号結果を反映させたい場合は、図７Ｂにおいて、ステップＳ４の前にステップＳ８－１で検出したい信号の軟判定送信シンボルb'_n（ｋ）を関数演算し、これを用いて、ステップＳ４では式（３１）の代りに式（４３）を用い、つまり式（２９）、式（３０）、式（４３）により干渉レプリカベクトル$\mathbf{B}'$（ｋ）を生成し、ステップＳ８－２で式（３７）の代りに式（４８）を用いればよい。前述したようにｆ（b'_n（ｋ）をαb'_n（ｋ）又はαb'_n（ｋ）^{2}とする場合で、αを変化させる場合はステップＳ８－１－１で処理回数あるいは復号されたフレーム全体の信頼度によりαを決定し、ステップＳ８－１－２で１＋（２α＋α^2）b'_n（ｋ）^{2}を演算してｆ（b'_n（ｋ））として用いればよい。

【００６０】この検出する信号に誤り訂正結果を反映させる手法は従来技術の項で説明したシングルユーザターボ受信機にも適用することができる。また、この検出する信号に誤り訂正結果を反映させる手法において、式（３９）及び（４０）に示した近似を適用することができ、この場合は、図７Ａ中に破線で示すようにフィルタ係数生成部３３３－１に、チャネル推定器２８から式（３８）に示す行列$\mathbf{h}$のみを入力すればよい。上述では適応フィルタ係数$\mathbf{w}_n$（ｋ）を式（３４）により求めた、つまりチャネル行列$\mathbf{H}$を用いて求めたが、チャネル行列$\mathbf{H}$を用いなくてもよい。即ち復号処理（ターボ受信処理）の１回目では、式（３４）中の誤差ベクトル$\mathbf{G}$は単位行列となる。従って、差分ベクトル$\mathbf{y}'$（ｋ）と、トレーニング信号又はこれと硬判定送信シンボル$\hat{b}_n$（ｋ）、好ましくは前述したように信頼度が高い$\hat{b}_n$（ｋ）とをフィルタ係数生成部３３３－１に入力して、ＲＬＳ（再帰的最小２乗法）などを適用して逐次的に適応フィルタ係数$\mathbf{w}_n$（ｋ）を算出してもよい。誤差ベクトル$\mathbf{G}$は離散的時刻ｋに依存するため、復号の繰り返し処理の２回目以降は、適応フィルタ係数$\mathbf{w}_n$（ｋ）をシンボル毎に更新する必要があり、先に述べたようにチャネル行列$\mathbf{H}$を用いて適応フィルタ係数$\mathbf{w}_n$（ｋ）を決定することが好ましい。

【００６１】<u>第４発明（チャネル推定）</u>

前述したように繰り返しチャネル推定にユニークワードのような既知情報のみならず、情報シンボルの硬判定値、特にその確からしいものも参照信号として用いることは、前記多入力多出力ターボ受信方法に利用する場合に限らず、一般的に、受信信号のチャネル（伝送路）を、受信信号と既知信号とから推定し、その推定したチャネル値を用いて受信信号を処理して復号を行い、その復号信号を利用して、同一受信信号を繰り返し、推定したチャネル値による処理と復号処理とを行うターボ受信方法に適用できる。

【００６２】図８に、この情報シンボルの硬判定値もチャネル推定、ターボイコライザ４１に適用した例を示す。ターボイコライザ４１は推定チャネル値により線形等化フィルタ係数を決定し、その線形等化フィルタにより受信信号を処理し、その処理した信号を復号し、その復号信号を利用して、同一受信信号を繰り返し処理する。受信信号ｒ（ｋ）はターボイコライザ４１へ入力されると共に、チャネル推定器４２へ供給され、チャネル推定器４２では受信信号ｒ（ｋ）と記憶部２９からのユニークワードとによりチャネル値（伝送路特性）が推定され、その推定されたチャネル値によりターボイコライザ４１内で受信信号ｒ（ｋ）が等化処理され、その後、復号処理され、復号データｃ′（ｉ）が出力されると共に、軟判定値ｂ′（ｉ）が出力される。軟判定値ｂ′（ｉ）はシンボル選定器４３に入力されその軟判定値ｂ′（ｉ）の絶対値がしきい値Ｔｈ以上であれば、その硬判定値$\hat{b}$（ｉ）が、確からしい（信頼性が高い）ものとして前回シンボル記憶部３２に更新格納され、以後における同一受信信号ｒ（ｋ）を繰り返し受信処理（イ

コライズ処理）する際のチャネル推定部４２におけるチャネル推定処理においては、ユニークワードのみならず、前回シンボル記憶部３２に記憶されている情報シンボルの硬判定値ｂ＾（ｉ）も用いる。

【００６３】ターボイコライザ４１は例えば図１に示した受信機中の繰り返しチャネル推定器２８、ユニークワード記憶部２９、前回シンボル記憶部３２を除いた部分である。図２９中の受信機であってもよい。つまり、この場合も式（１９）の解は、ウイーナー解により下記となる。

$$\mathbf{w}(k)=E[\mathbf{y}'(k)\,\mathbf{y}'^{H}(k)]\cdot E[b(k)\cdot\mathbf{y}'(k)]$$
$$=[\mathbf{H}\Lambda(k)\mathbf{H}+\sigma^2\mathbf{I}]\cdot\mathbf{h}\qquad(50)$$

ここで$\mathbf{H}$は式（８）で定義されたものであり、

$\mathbf{h}\equiv[\mathbf{H}(Q-1),\cdots,\mathbf{H}(0)]^T$

$\mathbf{H}(\ )$は式（５）で定義されたもの、$\sigma^2=E[\|v\|^2]$（雑音の分散）

$\Lambda(k)=\mathrm{diag}[1-b'^2(k+Q-1),\cdots,1,\cdots,1-b'^2(k-Q+1)]$

このように図２９中の受信機においても、チャネル$\mathbf{H}(\ )$を推定し、このチャネル$\mathbf{H}(\ )$を用いて等化フィルタ係数$\mathbf{w}(k)$求め、受信信号をフィルタ係数$\mathbf{w}(k)$でフィルタ処理し、その処理した出力に対し復号処理を行う。従ってこの繰り返し受信処理において、前記信頼性のある硬判定情報シンボルもチャネル推定に用いることにより、より正しいチャネル推定を得ることができる。

【００６４】図９はレーク（ＲＡＫＥ）合成処理を行う繰り返し受信に前記繰り返しチャネル推定方法を適用したターボ受信機の例を示す。受信信号ｒ（ｋ）はＲＡＫＥ合成処理部４５とチャネル推定器４２に供給される。１回目はチャネル推定器４２で受信信号ｒ（ｋ）とユニークワードとによりチャネル値が推定され、ＲＡＫＥ合成処理部４５内において、各シンボルが伝送路で受けた位相回転に対する補償とＲＡＫＥ合成処理が、推定されたチャネル値により行われ、つまり時間ダイバーシチ処理が行われてターボデコーダ４６へ出力される。ターボデコーダ４６より復号データｃ′（ｉ）と、軟判定値ｂ′（ｉ）が出力される。軟判定値ｂ′（ｉ）はシンボル選定器４３に入力され、前記例と同様に、その確らしいものの情報シンボルの硬判定値ｂ＾（ｉ）が前回シンボル記憶部３２に更新格納される。２回目以後のＲＡＫＥ受信－ターボデコーディングの繰り返し受信処理においては、チャネル推定器４２でユニークワードのみならず、前回の情報シンボルの硬判定値もチャネル推定に利用される。これにより、チャネルの推定がより正確に行えるため、品質の向上が図れる。

【００６５】図１０はアダプティブ（適応）アレーアンテナを用いた繰り返し受信に、前記繰り返しチャネル推定方法を適用したターボ受信機の例を示す。受信信号ｒ（ｋ）はアダプティブアレーアンテナ受信部４７に受信され、その受信信号はチャネル推定器４２に分岐入力され、これとユニークワードとによりチャネル推定が行われ、その推定したチャネル値を用いて、アダプティブアレーアンテナ受信部４７のアンテナ指向特性の主ビームが目的波の到来方向に向き、ヌルが干渉波の到来方向に向くように、アレー重み決定部４８で各アンテナ素子、又は対応する受信経路に対する重みが決定され、その重みが該当箇所に設定される。アダプティブアレーアンテナ受信部４７の受信出力はターボデコーダ４６へ供給されて復号され、その復号データｃ′（ｉ）と軟判定値ｂ′（ｉ）が出力され、軟判定値ｂ′（ｉ）はシンボル選定器４３に入力され、確からしい硬判定値が前回シンボル記憶部３２に更新記憶される。２回目以後のアダプティブアレーアンテナ受信部４７－ターボデコーダ４６の繰り返し受信処理においてはチャネル推定器４２でユニークワードのみならず、前回の情報シンボルの硬判定値もチャネル推定に利用される。これによりチャネル推定がより正しく行われ、その結果、アンテナ指向特性の制御がより正確に行われ、品質の向上が図れる。

【００６６】なお図８におけるターボイコライザ４１は簡略に示すと、図１１Ａに示すように軟入力軟出力（ＳＩＳＯ）イコライザ（等化器）４１ａとＳＩＳＯデコーダ（復号器）４１ｂの直列接続の形式であり、これら等化器４１ａと復号器４１ｂ間で繰り返し動作が行われる。図９及び図１０中のターボデコーダ４６は簡略に示すと、図１１Ｂに示すように、ＳＩＳＯデコーダ４６ａとＳＩＳＯデコーダ４６ｂの直列接続の形式であり、デコーダ４６ａと４６ｂ間で繰り返し復号が行われる。図９及び図１０中のターボデコーダ４６は、ＳＩＳＯデコーダ一つでもよい。

【００６７】以上の図８乃至図１０に示した例をまとめて図１２に示す。つまり受信信号を繰り返し受信機（ターボ受信機）４９でまず、チャネル推定器４２で推定したチャネル値により処理し、その処理した信号を復号処理し、その復号処理結果として復号データ（シンボル）ｃ′（ｉ）とその軟判定値ｂ′（ｉ）を出力し、その軟判定値ｂ′（ｉ）をシンボル選定器４３において、しきい値と比較して、対応復号データｃ′（ｉ）（シンボル硬判定値）が確からしいか否かを判定し、確からしいと判定されたものはその硬判定値を前回シンボル記憶部３２に更新格納して、２回目以後の推定チャネル値を用いた処理－復号処理の繰り返しにおけるチャネル推定器４２におけるチャネル推定に、ユニークワードのような既知情報の他に前回のシンボル硬判定値をも用いて、チャネル推定をより正確に行うようにするものである。

【００６８】図１３に、このシンボル硬判定値をも用い

る繰り返し受信信号方法の処理手順の例を示す。ステップＳ１で受信信号と既知信号とによりチャネル値を推定し、ステップＳ２で繰り返し処理の１回目が否かを調べ、１回目であればステップＳ３でステップＳ１で推定したチャネル値により受信信号を処理し、その後、復号処理を行ってシンボル硬判定値と軟判定値を求める。ステップＳ４でそのシンボル軟判定値から対応シンボル硬判定値の確からしいものを取出し、ステップＳ５でその取出したシンボル硬判定値に記憶部３２に記憶してある前回のシンボル硬判定を更新する。ステップＳ６で復号処理が所定回数かを調べ、所定回数になっていなければステップＳ１に戻る。ステップＳ２で繰り返し処理の１回目でなければ、ステップＳ７で記憶部３２から前回のシンボル硬判定値を読み出し、これと、受信信号の情報シンボルとによりチャネル推定を行ってステップＳ３に移る。

【００６９】この場合も、図６を参照してステップＳ１′～Ｓ４′により説明したように、２回目以後の処理は既知信号を用いなくてもよい。図１０に示した例においてアダプティブアレーアンテナ受信部４７とターボデコーダ４６との間に破線で示すようにＲＡＫＥ合成処理部４５を挿入してもよい。この場合、ＲＡＫＥ合成処理部４５における各シンボル位相回転補正、ＲＡＫＥ合成のためのチャネル推定は、チャネル推定器４２で兼用してもよく、個別に設けてもよい。

【００７０】白色性ガウス雑音以外の雑音

前述したターボ受信方法（第１発明）の実施例や誤り訂正を考慮した第２発明の実施例、またチャネル推定方法に特徴を有するターボ受信方法（第４発明）の実施例では雑音が白色性ガウス雑音であると仮定して処理した。即ち各アンテナの受信信号 $r_m(k)$ を示す式（２０）の右辺中の $v_m(k)$ を白色性ガウス雑音であると仮定をしている。ここで白色性ガウス雑音とは、ガウス分布に従い、

$E[v_m(k)\cdot v_m(k-q)]=\sigma^2$ ：$q=0$の場合，0：$q\neq 0$の場合

$E[\,]$ は期待値、σ^2 は分散値である。なる統計的性質を有する信号である。白色性ガウス雑音はアンテナ素子内で発生する熱雑音などが例に挙げられる。この白色性ガウス雑音の仮定が反映されるのは、フィルタ係数 $\mathbf{w}_n(k)$ を求める式（３４）又はフィルタ係数 $\mathbf{w}(k)$ を求める式（５０）中の $\sigma^2\mathbf{I}$ の部分である。例えば式（３４）の $\mathbf{w}_n(k)$ は、

$$\mathbf{w}_n(k)=(\mathbf{H}\mathbf{G}(k)\mathbf{H}^H+E[\mathbf{n}(k)\cdot\mathbf{n}^H(k)])^{-1}\mathbf{h}$$
$$=(\mathbf{H}\mathbf{G}(k)\mathbf{H}^H+\sigma^2\mathbf{I})^{-1}\mathbf{h}$$

の過程を経て算出される。ここで、$v_m(k)$ が分散 σ^2 を有する白色性ガウス雑音という仮定により、$E[\mathbf{n}(k)\cdot\mathbf{n}^H(k)]=\sigma^2\mathbf{I}$ と計算される。繰り返しチャネル推定器２８（図１）又は４２（図１２）により推定される、チャネル行列 $\mathbf{H}$ と、σ^2 と、事前対数尤度値から計算される誤差行列 $\mathbf{G}(k)$ とを、式（３４）に代入してフィルタ係数 $\mathbf{w}_n(k)$ が算出される。

【００７１】所で、雑音 $v_m(k)$ が白色性ガウス雑音でない場合を考える。この場合は、$E[\mathbf{n}(k)\cdot\mathbf{n}^H(k)]=\sigma^2\mathbf{I}$ とすることができないため、フィルタ係数 $\mathbf{w}_n(k)$ を算出するために、雑音成分の期待値（共分散）行列 $E[\mathbf{n}(k)\cdot\mathbf{n}^H(k)]$ を別の方法で推定する必要がある。以下にこの方法を説明する。ここで雑音成分の共分散行列を $U\equiv E[\mathbf{n}(k)\cdot\mathbf{n}^H(k)]$ と略記する。式（２２）の $\mathbf{y}(k)=\mathbf{H}\cdot\mathbf{B}(k)+\mathbf{n}(k)$ を $\mathbf{n}(k)=\mathbf{y}(k)-\mathbf{H}\cdot\mathbf{B}(k)$ と変形して、共分散行列Ｕに代入すると次式となる。

【００７２】

$$U=E[\mathbf{n}(k)\cdot\mathbf{n}^H(k)]$$
$$=E[(\mathbf{y}(k)-\mathbf{H}\cdot\mathbf{B}(k))\cdot(\mathbf{y}(k)-\mathbf{H}\cdot\mathbf{B}(k))^H]$$

今、受信信号によりベクトル $\mathbf{y}(k)$、チャネル推定値によりチャネル行列 $\mathbf{H}$ の推定値 $\hat{\mathbf{H}}$、参照信号により $\mathbf{B}(k)$ が利用可能であれば、行列Ｕは時間平均法により、

$$\hat{U}=\sum_{k=0}^{Tr}(\mathbf{y}(k)-\hat{\mathbf{H}}\cdot\mathbf{B}(k))\cdot(\mathbf{y}(k)-\hat{\mathbf{H}}\cdot\mathbf{B}(k))^H \qquad (51)$$

と推定することができる。ここで、Ｔｒは参照信号シンボル数である。

【００７３】繰り返しチャネル推定器２８又は４２における繰り返しチャネル推定中にチャネル行列 $\mathbf{H}$ とともに、式（５１）を利用して共分散行列 $\hat{U}$ を推定する。その手順を図１４に示す。図１４Ａに受信信号中の１フレームにおけるユニークワードと情報シンボル系列とを示し、図１４Ｂに１回目以後の処理を示す。１回目の処理はユニークワードのみを参照信号とし、まずチャネル行列 $\mathbf{H}$ を推定する。次にユニークワードと、そのチャネル行列推定値 $\hat{\mathbf{H}}$ を用いて式（５１）により、Ｕを推定する。これら推定値Ｕと $\hat{\mathbf{H}}$ を用いてフィルタ係数 $\mathbf{w}_n(k)$

$$\mathbf{w}_n(k)=(\hat{\mathbf{H}}\mathbf{G}(k)\hat{\mathbf{H}}^H+\hat{U})^{-1}\mathbf{h} \qquad (52)$$

を算出し、このフィルタ係数$\mathbf{w}_n$（ｋ）を用いて受信信号に対する１回目の等化を行い送信情報シンボルを推定する。

【００７４】２回目の処理はユニークワードと、１回目の等化で推定された情報シンボルのうちしきい値によって確からしいと判定されたもの＊との両方を参照信号として、１回目と同じ手順で$\mathbf{H}$を再推定した後、Ｕを再推定する。この操作を繰り返すことによって、繰り返し毎に、チャネル行列推定値$\mathbf{H}$＾がより正確になり、またＵの推定値がより正確になり、フィルタ係数$\mathbf{w}_n$（ｋ）の精度が上がり、等化器の特性が向上する。以上の処理により白色性ガウス雑音でない雑音が受信信号に含まれる場合のターボ受信を行うことができる。

【００７５】前述した受信信号中のその雑音の共分散行列Ｕを推定して線形等化処理を行う場合の機能構成を、図２中に示した多出力等化器３１の第１番目の送信機からの送信信号の受信信号の等化出力として対数尤度比Λ_1［b_1（ｋ）］を求める場合に適用した例を図１５に示す。図１５中の図２と対応する部分には同一参照番号を付けてある。ユニークワード記憶部２９からのユニークワード又は前回シンボル記憶部３２から確からしい前回のシンボル硬判定が参照ベクトル生成部３１９に入力され、ここで式（２５）及び式（２６）により参照ベクトル$\mathbf{B}$（ｋ）が生成される。この参照ベクトル$\mathbf{B}$（ｋ）と、チャネル推定器２８からの推定チャネル行列Ｈ＾と、受信ベクトル生成部３１１からの受信ベクトル$\mathbf{y}$（ｋ）が共分散行列推定部３２１に供給され、ここで式（５１）が計算されて共分散行列Ｕの推定行列Ｕ＾が得られる。

【００７６】また軟判定シンボル生成部３１３－１からの軟判定送信シンボル軟判定b'_1（ｋ）～b'_n（ｋ）が誤差ベクトル生成部３２２－１に入力され、ここで式（３５）、式（３６）及び式（３７）によりチャネル推定２乗誤差と対応する誤差行列$\mathbf{G}_1$（ｋ）が生成される。この誤差行列$\mathbf{G}_1$（ｋ）と、推定共分散行列Ｕ＾と、推定チャネル行列$\mathbf{H}$＾とがフィルタ推定部３２３－１へ供給され、ここで式（５２）が計算されてフィルタ係数$\mathbf{w}_1$（ｋ）が推定される。このフィルタ係数$\mathbf{w}_1$（ｋ）と差演算部３１６－１からの差分ベクトル$\mathbf{y}'$（ｋ）が適応フィルタ３１８－１へ供給されて、$\mathbf{y}'$（ｋ）に対するフィルタ処理$\mathbf{w}_1$（ｋ）$^H\mathbf{y}'$（ｋ）がなされ、その結果が対数尤度比Λ_1［b_1（ｋ）］として出力される。

【００７７】検出する信号についても誤り訂正復号結果を反映させる場合は、図１５中に破線で示すように、図７Ａに示した関数演算部３３１－１を設けてｆ（b'_n（ｋ））を演算し、干渉レプリカベクトル生成部３１４－１では式（３１）の代りに式（４３）を用い、誤差ベクトル生成部３２２－１では式（３７）の代りに式（４８）を用いればよい。図１４Ｂに示した手法を図１６に流れ図として示す。つまりステップＳ１で受信信号ｒ（ｋ）と既知信号（例えばユニークワード）を用いてチャネル行列$\mathbf{H}$を推定し、次はステップＳ２でこの処理が繰り返し処理における１回目であるか否かを調べ、１回目であれば、ステップＳ３で既知信号と推定チャネル行列$\mathbf{H}$＾と、受信信号ｒ（ｋ）とを用いて式（５１）を演算して推定共分散行列Ｕ＾を求める。

【００７８】ステップＳ４で推定チャネル行列$\mathbf{H}$＾と、推定共分散行列Ｕ＾と、シンボル軟判定値によりなる誤差行列$\mathbf{G}$（ｋ）とを用いて式（５２）を計算してフィルタ係数$\mathbf{w}_n$（ｋ）を推定する。ステップＳ５で推定チャネル行列$\mathbf{H}$＾とフィルタ係数$\mathbf{w}_n$（ｋ）を用いて受信信号を等化処理し、つまり式（２７）を計算し、$\mathbf{w}_n^H$（ｋ）・$\mathbf{y}'$（ｋ）を計算して、対数尤度比Λ_1［b_n（ｋ）］を求め、これに対し復号処理を行って送信シンボルの硬判定値及び軟判定値を推定する。

【００７９】ステップＳ６はしきい値以上のシンボル軟判定値より対応する確からしい（信頼性の高い）シンボル硬判定値を求める。このシンボル硬判定値により、前回シンボル記憶部３２に格納されているシンボル硬判定値を更新する。その後、ステップＳ８で復号処理回数が所定値になったかを調べ、なっていなければステップＳ１に戻り、所定値になっていれば、その受信フレームに対する処理を終了する。ステップＳ２で繰り返し処理における処理が１回目でなければ、つまり２回目以後であれば、ステップＳ９で前回シンボル記憶部３２からシンボル硬判定値を読み出し、これと、受信信号中の情報シンボルとによりチャネル行列$\mathbf{H}$を推定してステップＳ３に移る。

【００８０】この場合も、図６中で破線で示したステップＳ１′～Ｓ４′と同様の処理にステップＳ１とＳ２を変更することにより、２回目以後は、既知信号を用いないようにすることもできる。また検出する信号も誤り訂正復号結果を反映させたい場合は図１６中に破線で示すようにステップＳ１０で関数演算ｆ（b'_n（ｋ））を行い、この結果を用いて誤差行列$\mathbf{G}$（ｋ）を求めればよい。更に何れの場合においても共分散行列Ｕ＾の推定に硬判定送信シンボルを用いなくてもよい。この白色性ガウス雑音でない雑音が含まれた受信信号中のその雑音の共分散行列Ｕを推定できることは以下に述べるように各種有益な応用に適用することができる。

【００８１】（１）受信機が未知の干渉信号が含まれる多系列送信信号に対する受信法が挙げられる。図２８に示すように、ターボ受信機が受信しようとするＮ人のユーザの送信機からの信号のように、Ｎ個の系列の送信信号に加え、破線で示すようにターボ受信機で未知の干渉信号ｉ（ｋ）（例えば移動通信で他のセルやゾーンからの信号）が受信されるとする。このとき式（２０）は、

$$r_m(k)=\Sigma_{q=0}^{Q-1}\ \Sigma_{n=1}^{N}h_{mn}(q)\cdot b_n(k-q+1)+i(k)+v_m(k) \quad (20)'$$

となる。このモデルにおいて、$i(k)+v_m(k)\equiv v'_m(k)$とすると、

$$r_m(k)=\Sigma_{q=0}^{Q-1}\ \Sigma_{n=1}^{N}h_{mn}(q)\cdot b_n(k-q+1)+v'_m(k) \quad (20)''$$

となる。$v'_m(k)$は白色性ガウス雑音でない雑音信号として、先に述べたように$\mathbf{H}$の推定、更にUの推定を行い、$\mathbf{w}_n(k)$を推定し、受信信号の等化処理、送信シンボル推定を繰り返すことによりターボ受信を行うことができる。

【００８２】（２）送受信分離フィルタを用いた通信システムにおいて、受信信号に対し、シンボル周期の２分の１よりも高速でオーバーサンプリングを行う際には、各時間でサンプルされた受信信号に含まれる雑音成分間に相関が出て、受信信号中の雑音を白色性ガウス雑音とみなすことができない。つまり、式（２０）において、

$E[v_m(k)\cdot v_m(k-q)]=\sigma^2$：$q=0$の場合，$0$：$q\neq 0$の場合

とはならない。よって

$E[\mathbf{n}(k)\cdot\mathbf{n}^H(k)]=\sigma^2\ \mathbf{I}$

なる仮定ができない。そこで送受信分離フィルタにより分離された受信信号に対する処理を式（５１）を利用して共分散行列Uを求めて行うことにより、受信信号を正しく処理することができる。

【００８３】（３）前述したターボ受信方法では、各送信機（ユーザ）からのQパスのマルチパス成分をすべて合成するしくみになっている。しかし、チャネルに長遅延波が存在する場合（例：パスが１シンボル遅延、２シンボル遅延、３シンボル遅延、とんで、３０シンボル遅延が存在する場合の３０シンボル遅延のパス成分）は、長遅延波を合成せず、それを未知干渉として扱い、適応フィルタで除去する方針をとることが可能である。つまりこの長遅延波成分を前記（１）の例における干渉信号$i(k)$として扱うことで長遅延波を除去することができる。

【００８４】上述した白色性ガウス雑音でない雑音が含まれた受信信号に対する処理において、共分散行列Uの推定は式（５０）における$\sigma^2\ \mathbf{I}$の代りに推定して、シングルユーザターボ受信方法にも適用でき、同様にシングルユーザ、マルチユーザに拘らず、図９に示したRAKE合成処理受信や図１０に示したアダプティブアレーアンテナ受信を用いるターボ受信、更に一般に図１２に示した繰り返し復号におけるチャネル推定器４２でのチャネル推定と共分散行列Uとの推定に適用できる。なおRAKE受信の場合はチャネル推定のみを利用してもよい。

【００８５】<u>第３発明（多段等化）</u>

上述では受信信号r_1，…，r_Mを多出力等化器３１で等化して対数尤度比$\Lambda_1[b(k)]$，…，$\Lambda_N[b(k)]$を求めたが、第１発明の変形例（２）では複数の等化段を縦続的に設け、後段の等化器程、出力数を少なくする構成としてもよい。例えばこれを図１７に示すように二つに分け前段等化器（マルチユーザ等化器）７１で、後段のシングルユーザ等化器２１′の等化範囲外の干渉成分をキャンセルし、そのため例えばソフト干渉キャンセルとMMSE（最小平均２乗誤差）規範線形フィルタリングの前処理を行い、その後、後段等化器２１′により、先に示したパス数がQのシングルユーザの等化処理を行う。

【００８６】このように縦続的に等化処理し、前段の処理に線形フィルタを用いることによっても計算量が莫大なものにならないようにすることができる。このターボ受信法の第１発明（２）の基本的概念をもとにした実施例の多出力ターボ受信機の構成及びこの発明が適用されるMIMOシステムの構成例を図１８に示し、図１と対応する部分に同一参照番号を付けて重複説明を省略する（以下の説明も同様）。伝送路（チャネル）を通じてターボ受信機３０に、各送信機よりの送信信号が受信される。この受信信号$\mathbf{r}(k)$はマルチユーザ等化器７１に入力され、この等化器７１から、N個の各送信機よりの信号が、それぞれ他の送信機からの信号による干渉が除去された信号$u_1(k)$，…，$u_N(k)$と各チャネル値$\alpha_1(k)$，…，$\alpha_N(k)$が出力されてそれぞれシングルユーザ等化器２１－１，…，２１－Nに入力され、これらSISO等化器２１－１，…，２１－Nからそれぞれ対数尤度比$\Lambda_1[b_1(k)]$，…，$\Lambda_1[b_N(k)]$が出力される。これより以後の処理は図１の場合と同様であるが、シングルユーザ等化器２１－１，…，２１－Nで用いられるチャネル値$\alpha_1(k)$，…，$\alpha_N(k)$はマルチユーザ等化後のチャネル値であり、チャネル行列$\mathbf{H}$とは異なる。よってこの$\alpha_1(k)$，…，$\alpha_N(k)$を等化後のチャネル情報と記す。

【００８７】以下、各部の動作を説明する。マルチパス（チャネル）の数Qを考慮して図１の説明と同様に式（２３）～（２６）を定義する。図１８中の後段の等化器２１－１，…，２１－Nは各ユーザの自身の信号シンボル$[b_n(k),b_n(k-1),…,b_n(K-Q+1)]$（$n=1,…,N$）による符号間干渉チャネルを等化するものである。そのため前段の等化器７１では$\mathbf{y}(k)$内の上記$[b_n(k),b_n(k-1),…,b_n(K-Q+1)]$（$n=1,…,N$）以外の干渉を除去する処理を行う。以下にその定量的な説明を行う。

【００８８】まず、復号器２４－１，…，２４－Nから

フィードバックされる等化器７１の事前情報$\lambda_2{}^p$［b_n（ｋ）］（ｎ＝１，…，Ｎ）を用いて軟判定送信シンボル推定b'（ｋ）を式（１５）により求める。次にこれら軟判定送信シンボルb'_n（ｋ）とチャネル行列$\mathbf{H}$を用いて干渉信号のレプリカ$\mathbf{H}\cdot\mathbf{B}'$（ｋ）を作成し、受信ベクトル$\mathbf{y}$（ｋ）から引算する。

$$\mathbf{y}'_n(k) \equiv \mathbf{y}(k) - \mathbf{H}\cdot\mathbf{B}'(k) \qquad (27)'$$

$$= \mathbf{H}\cdot(\mathbf{B}(k) - \mathbf{B}'(k)) + \mathbf{n}(k) \qquad (28)'$$

ここで、

$$\mathbf{B}'(k) = [\mathbf{b}'^T(k+Q-1)\cdots\mathbf{b}'^T(k)\cdots\mathbf{b}'^T(k-Q+1)]^T \qquad (29)'$$

そして、

$$\mathbf{b}'(k+q) = [b'_1(k+q)\ b'_2(k+q)\cdots b'_n(k+q)\cdots b'_N(k+q)]^T : q=Q-1,\cdots,1 \qquad (53)$$

$$\mathbf{b}'(k+q) = [b'_1(k+q)\ b'_2(k+q)\cdots 0\cdots b'_N(k+q)]^T : q=0,\cdots,-Q+1 \qquad (54)$$

（$\mathbf{b}'$（ｋ＋ｑ）の要素中のゼロはｎ番目）

以下この干渉を引算する操作をソフト干渉キャンセルと呼ぶことにする。理想的に干渉信号のレプリカが作られているとすると、引算後得られる$\mathbf{y}'_n$（ｋ）は第ｎ番目のユーザのシンボルb_n（ｋ）と、式（５４）によりｑ＝１，…，－Ｑ＋１で$\mathbf{b}'$（ｋ＋ｑ）のｎ番目の要素を０としたことに基ずくその第ｎ番目のユーザ自身のシンボル［b_n（ｋ－１），…，b_n（ｋ－Ｑ＋１）］による符号間干渉成分としか持ち得ないことが分かる。

【００８９】実際受信ベクトル$\mathbf{r}$（ｋ）内の第ｎ番目ユーザ（送信機）の信号からの寄与成分はシンボル［b_n（ｋ），b_n（ｋ－１），…，b_n（ｋ－Ｑ＋１）］によるもののみだが、式（２１）の受信ベクトル$\mathbf{y}$（ｋ）の定義から理解されるように、マルチパス分合成して作られる受信ベクルト$\mathbf{y}$（ｋ）内の第ｎ番目ユーザ（送信機）の信号からの寄与成分にはｋ番目のシンボルb_n（ｋ）を基準にすればこれに対して未来のシンボル［b_n（ｋ＋Ｑ－１），b_n（ｋ＋Ｑ－２），…，b_n（ｋ＋１）］による符号間干渉成分も含んでしまう。つまり上記干渉レプリカはその未来からの干渉成分も含めている。このように式（２７）’の差分ベクトル$\mathbf{y}'$（ｋ）は式（２７）の差分ベクトル$\mathbf{y}'$（ｋ）と異なっている。

【００９０】そこで等化器７１における前段処理の次のステップはソフト干渉キャンセル後の干渉余剰成分、つまり前記干渉レプリカ$\mathbf{H}\cdot\mathbf{B}'$（ｋ）の不完全合成に基づく残余干渉成分と前記未来符号間干渉成分とを$\mathbf{y}'_n$（ｋ）からＭＭＳＥ（最小平均２乗誤差）規範の線形フィルタにより除去する。つまり、フィルタ特性$\mathbf{w}_n$により$\mathbf{y}'_n$（ｋ）を、式（５５）に示すようにフィルタ処理した結果が、受信信号中の第ｎ番目ユーザの信号中のシンボル［b_n（ｋ），b_n（ｋ－１），…，b_n（Ｋ－Ｑ＋１）］にチャネル値α_{1n}，α_{2n}，…，α_{Qn}をそれぞれ乗算した和と等しくなるようにする。

$$\mathbf{w}_n{}^H(k)\cdot\mathbf{y}'_n(k) \fallingdotseq \sum_{q=0}^{Q-1}\alpha_q(k)\cdot b_n(k-q) = \boldsymbol{\alpha}_n{}^H(k)\cdot\mathbf{b}_n(k) \qquad (55)$$

従ってこのフィルタ特性$\mathbf{w}_n$（ｋ）及び等化後のチャネル値（チャネル情報）$\boldsymbol{\alpha}_n$（ｋ）を求めて式（５５）を演算すればよい。以下に$\mathbf{w}_n$（ｋ），$\boldsymbol{\alpha}_n$（ｋ）の算出方法を示す。なおフィルタ特性$\mathbf{w}_n$（ｋ）は式（３２）、式（３４）で与えられるフィルタ係数$\mathbf{w}_n$（ｋ）とは異なっているが便宜上同一記号を用いる。

【００９１】上記の解は以下の最適問題の解として定義される。

$$(\mathbf{w}_n(k), \boldsymbol{\alpha}_n(k)) = \arg\min \| \mathbf{w}_n{}^H(k)\cdot\mathbf{y}'_n(k) - \boldsymbol{\alpha}_n{}^H(k)\cdot\mathbf{b}_n(k)\|^2 \qquad (56)$$

α_{1n}（ｋ）＝１を条件とする。つまり式（５６）の右辺が最小となる$\mathbf{w}_n$（ｋ）と$\boldsymbol{\alpha}_n$（ｋ）を求める。付加された拘束条件α_{1n}（ｋ）＝１は、$\boldsymbol{\alpha}_n$（ｋ）＝０，$\mathbf{w}_n$（ｋ）＝０なる解を避ける為である。これは、‖$\boldsymbol{\alpha}_n$（ｋ）‖^2＝１なる拘束条件で解く事も可能であるが以下では、α_{1n}（ｋ）＝１の場合の解を示す。簡単の為、以下のように問題を置き換える。つまり式（５６）の右辺を$\mathbf{w}$，$\boldsymbol{\alpha}$について最小とする$\mathbf{m}_n$（ｋ）と定義する。

【００９２】

$$\mathbf{m}_n(k) = \arg\min \|\mathbf{m}_n{}^H(k)\cdot\mathbf{z}_n(k)\|^2 \qquad (57)$$

$\mathbf{m}_n{}^H(k)\cdot\mathbf{e}_{MQ+1} = -1$を条件とする。（$\alpha_{1n}$（ｋ）＝１と等価）

ここで、

$$\mathbf{m}_n(k) \equiv [\mathbf{w}_n{}^T(k), -\boldsymbol{\alpha}_n(k)^T]^T \qquad (58)$$

$$\mathbf{z}_n(k) \equiv [\mathbf{y}_n{}^T(k), \mathbf{b}(k)_n{}^T]^T \qquad (59)$$

$$e_{MQ+1}=[0\cdots1\cdots0]^T \quad (60)$$

（e_{MQ+1}中の１の要素はMQ＋１番目）である。文献［２］S.Haykin,Adaptive Filter Theory,Prentice Hall P.220～P227に示されているラグランジェ未定係数法より、この最適化問題の解は以下で与えられる。

【００９３】

$$m_n(k)=-R_{ZZ}^{-1}\cdot e_{MQ+1}/(e_{MQ+1}^H\cdot R_{ZZ}^{-1}\cdot e_{MQ+1}) \quad (61)$$

ここで、

$$R_{ZZ}=E[z_n(k)\cdot z_n^H(k)] \quad (62)$$

E［A］はAの期待値（平均値）を表わす。

【００９４】

【００９５】

【数２１】

$$=E\begin{bmatrix} H\cdot\Lambda_n(k)\cdot H^H+\sigma^2 I & H_n^H \\ H_n & I \end{bmatrix} \quad (63)$$

$$\Lambda_n(k)=\mathrm{diag}[D_n(k+Q-1),\cdots,D_n(k),\cdots,D_n(k-Q+1)] \quad (64)$$

I は単位行列　σ^2 は雑音電力（白色性ガウス雑音の分散値）

【００９６】

【００９７】

【数２２】

$$H_n=\begin{bmatrix} h_n(Q-1) & 0 & 0 & 0 \\ h_n(Q-2) & h_n(Q-1) & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots \\ h_n(0) & h_n(1) & \cdots & h_n(Q-1) \end{bmatrix} \quad (65)$$

$$D_n(k+q)=\mathrm{diag}[1-b'_1{}^2(k+q),\cdots,1-b'_n{}^2(k+q),\cdots,1-b'_N{}^2(k+q)] \quad :q=Q+1,\cdots,1 \quad (66)$$

$$D_n(k+q)=\mathrm{diag}[1-b'_1{}^2(k+q),\cdots,1,\cdots,1-b'_N{}^2(k+q)] \quad :q=0,\cdots,-Q+1 \quad (67)$$

ｄｉａｇは対角行列（行列の対角線の要素以外の要素はゼロ）を表わす。つまりチャネル行列H、σ^2が既知であれば、$m_n(k)$は式（６１）で求めることができる。よって式（５８）に従い$w_n(k)$，$\alpha_n(k)$も求められる。

【００９８】この算出されたフィルタ特性$w_n(k)$により、$y'_n(k)$を次式によりフィルタ処理する。

$$u_n(k)=w_n^H(k)\cdot y'_n(k) \quad (68)$$

Hは共役転置行列を表わす。このフィルタ処理されたｎ個の処理結果が後続の対応する等化器２１－ｎに送られる。 このようにして第ｎ番目のユーザよりの式（１）の左辺と対応する受信信号$u_n(k)$が得られ、また式（１）の右辺のチャネル値$h_{mn}(q)$と対応する$\alpha_{mn}(k)$が得られ、つまり式（１）と対応する式（５５）が求まる。よって$\alpha_n(k)$も等化器パラメータ（チャネル値）として後続の等化器２１－ｎに付与される。以上が等化器７１による前段処理である。

【００９９】次に後続の等化器２１－ｎ以降の処理について述べる。前述したように式（５５）は式（１）と対応しているから、ユーザ毎の等化器２１－ｎ内での動作は図３１中の等化器２１の動作と同様に行えばよく上記でも述べた通り、文献［１］に示されているため詳細は省略する。各等化器２１－ｎは上で定義した$u_n(k)$，$\alpha_n(k)$及び復号器２４－ｎからの事前情報$\lambda_2[b_n(k)]$を入力し、出力として各符号化ビットが＋１である確率と－１である確率の対数尤度比Λ_1（ＬＬＲ：Log-Likelihood Ratio）を次式により算出する。

【０１００】

【数２３】

$$\Lambda_1[b(k)] = \log\frac{\Pr[b_n(k)=+1\,|\,u_n(k),k=0,\cdots,B]}{\Pr[b_n(k)=-1\,|\,u_n(k),k=0,\cdots,B]} \tag{69}$$

$$\equiv \lambda_1[b_n(k)] + \lambda_2^p[b_n(k)] \tag{70}$$

【０１０１】ここでλ_1 ［b_n （ｋ）］は後続の復号器２４－ｎに送られる外部情報、$\lambda_2{}^p$ ［b_n （ｋ）］は等化器３１に与えられる事前情報である。復号器２４－ｎは対数尤度比Λ_2 を次式により算出する。

【０１０２】

【数２４】

$$\Lambda_2[b_n(i)] = \log\frac{\Pr[b_n(i)=+1\,|\,\lambda_1[b_n(i)],i=0,\cdots,B]}{\Pr[b_n(i)=-1\,|\,\lambda_1[b_n(i)],i=0,\cdots,B]} \tag{71}$$

$$\equiv \lambda_2[b_n(i)] + \lambda_1^p[b_n(i)] \tag{72}$$

【０１０３】ここでλ_2 ［b_n （ｉ）］は繰り返しの際に等化器７１と等化器２１に与えられる外部情報、$\lambda_1{}^p$ ［b_n （ｋ）］は復号器２４－ｎに与えられた事前情報である。この図１８に示した構成により繰り返し等化、復号を行い誤り率の向上が達成される。前述したマルチユーザ等化器７１の機能構成を図１９を参照して簡単に説明する。各アンテナよりの受信信号は受信部７０でベクトル $\boldsymbol{r}$ （ｋ）＝［r_1 （ｋ）…r_M （ｋ）］として処理され、このベクトル $\boldsymbol{r}$ （ｋ）を用いて受信ベクトル生成部３１１において各マルチパス（チャネル）を考慮した式（２１）の受信ベクトル $\boldsymbol{y}$ （ｋ）が生成される。

【０１０４】一方、受信部７０よりの受信信号 $\boldsymbol{r}$ （ｋ）と、ユニークワード記憶部２９からの各送信機と対応した、チャネル推定用のユニークワード系列などの既知系列信号とがチャネル推定器２８に入力されてチャネル行列 $\boldsymbol{H}$ が推定される。また各復号器２４－１，…，２４－Ｎの出力対数尤度比Λ_2 ［b_1 （ｉ）］，…，Λ_2 ［b_N （ｉ）］からそれぞれ事前情報$\lambda_1{}^p$ ［b_1 （ｉ）］，…，$\lambda_1{}^p$ ［b_N （ｉ）］が差し引かれた外部情報λ_2 ［b_1 （ｋ）］，…，λ_2 ［b_N （ｋ）］が軟判定シンボル推定部３１３－１，…，３１３－Ｎに入力され、それぞれ式（１５）により軟判定送信シンボルb'_1 （ｋ），…，b'_N （ｋ）が計算され、これらが干渉ベクトル生成部７２に入力され、干渉ベクトル生成部７２では各ｎごとに他の送信機からの干渉信号となり得るシンボル推定値のベクトル $\boldsymbol{B}'$ （ｋ）が式（２９）′、（５３）及び（５４）により生成される。これらＮ個のベクトル $\boldsymbol{B}'$ （ｋ）とチャネル行列 $\boldsymbol{H}$ との積が他干渉信号推定部７３－１，…，７３－Ｎでそれぞれ演算されて干渉成分のレプリカ $\boldsymbol{H}\cdot\boldsymbol{B}$ （ｋ）が求められる。

【０１０５】これらＮ個の干渉成分レプリカ $\boldsymbol{H}\cdot\boldsymbol{B}$ （ｋ）が受信ベクトル $\boldsymbol{y}$ （ｋ）から引算部７４－１，…，７４－Ｎでそれぞれ引算されて、差分ベクトル $\boldsymbol{y}'_1$ （ｋ），…，$\boldsymbol{y}'_N$ （ｋ）が求められる。軟判定送信シンボルb'_1 （ｋ），…，b'_N （ｋ）が誤差行列生成部７５に入力されて、式（６４）、（６６）、（６７）により誤差行列Λ_1 （ｋ），…，Λ_N （ｋ）が生成され、これらとチャネル行列 $\boldsymbol{H}$ 及び雑音電力σ^2 がフィルタ特性推定部７６に入力され、フィルタ特性推定部７６では式（５８）、（６０）、（６１）、（６３）及び（６５）により、フィルタ特性 $\boldsymbol{w}_n$ と等化後のチャネル情報 $\boldsymbol{\alpha}_n$ とが推定される。これらフィルタ特性 $\boldsymbol{w}_1$ ，…，$\boldsymbol{w}_N$ と差分ベクトル $\boldsymbol{y}'_1$ （ｋ），…，$\boldsymbol{y}'_N$ （ｋ）とがフィルタ処理部７７－１，…，７７－Ｎでそれぞれ乗算され、つまりフィルタ処理されて、各ユーザごとの各パスからのシンボル［b_n （ｋ），b_n （ｋ－１），…，b_n （Ｋ－Ｑ＋１）］の受信信号から他ユーザ信号よりの干渉が除去された成分であるu_1 （ｋ），…，u_N （ｋ）がそれぞれ得られ、これらとフィルタ特性推定部７６で求められた等化後のチャネル情報 $\boldsymbol{\alpha}_1$ （ｋ），…，$\boldsymbol{\alpha}_N$ （ｋ）がそれぞれ図１８中のシングルユーザ等化器２１－１，…，２１－Ｎへ供給される。

【０１０６】このターボ受信法の第１発明（２）の処理手順を図２０に示す。図２０において、図３に示した処理手順と対応するステップには同一ステップ記号を付けた。ただし、ステップＳ４における干渉レプリカベクトル $\boldsymbol{B}'_n$ （ｋ）の計算は式（２９）′、（５３）及び（５４）により行う。ステップＳ１３は軟判定送信シンボルb'_n （ｋ）を用い、式（６４）、（６６）、（６７）により誤差行列Λ_n （ｋ）を生成する。ステップＳ１４はチャネルと行列 $\boldsymbol{H}$ 及び雑音電力σ^2 と誤差行列Λ_n （ｋ）を用い、式（５８）、（６０）、（６１）、（６３）、（６５）により残余干渉除去フィルタ $\boldsymbol{w}_n$ （ｋ）とチャネル情報 $\boldsymbol{\alpha}_n$ を求める。ステップＳ１５で差分ベクトル $\boldsymbol{y}'_n$ （ｋ）を残余干渉除去フィルタ特性 $\boldsymbol{w}_n$ （ｋ）によりフィルタ処理してu_n （ｋ）を求める。ステップＳ１６で各フィルタ処理結果ｕ

$_n$（ｋ）に対し、シングルユーザ等化処理を行って対数尤度比Λ_n［b_n（ｋ）］をそれぞれ求め、これらをステップＳ１０で復号処理する。その他は図３に示した処理と同様である。

【０１０７】上述では後段等化器２１－ｎにおける等化範囲は、シンボル［b_N（ｋ），b_n（ｋ－１），…，b_n（Ｋ－Ｑ＋１）］（ｎ＝１，…，Ｎ）による符号間干渉区間としているが、この等化範囲は調節可能である。例えば、Ｑが非常に大きな値の場合は、後段の等化器２１－ｎの計算負荷が大きくなる。このような場合、後段等化器２１－ｎでの等化範囲をＱ′＜Ｑとし、前段の等化器７１で、［b_n（ｋ），b_n（ｋ－１），…，b_n（Ｋ－Ｑ′＋１）］（Ｑ′＜Ｑ，ｎ＝１，…，Ｎ）区間以外の同一ユーザの信号の符号間干渉を除去するように変更すればよい。この変更については後で説明する。この前段等化と後段等化に分けて信う場合も、図１９中に破線で示すようにチャネル推定器２８において前回シンボル記憶部３２を設けて硬判定送信シンボル$\hat{b}_n$（ｋ）をも用いてチャネル値の推定を行うようにして、その推定精度を向上させることができる。

【０１０８】図１７に示した例では前段の多出力等化器７１ではＮ系列の送信信号に対し、これらを他系列よりの干渉を等化分離した、Ｎ系列の信号u_nと、等化後のチャネル情報α_nを出力し、その後、各Ｎ系列の信号u_nを後段のシングルユーザ等化器２２－ｎにより同一送信信号の符号間干渉を除去した。つまり、２段の縦続等化構成とした。３段以上の縦続多段構成としてもよい。例えば図２１に示すように、第１段目の等化器８１において、Ｎ系列の送信信号に対するＭ系列の受信信号r_mを入力して第１～第Ｕ番送信系列の第Ｕ＋１番送信系列による干渉を除去した等化信号系列er_1（ｋ）及びその等化後のチャネル情報$e\alpha$（ｋ）と、第Ｕ＋１～第Ｎ番送信系列の第１～第Ｕ番送信系列による干渉を除去した等化信号系列er_2（ｋ）及びその等化後のチャネル情報$e\alpha_2$（ｋ）とを得、第２段目の等化器８２－１及び８２－２中の８２－１では、入力されたer_1（ｋ）及び$e\alpha_1$（ｋ）を等化処理して、第１～第Ｕ番送信系列中の第１～第U_1番送信系列の第U_1＋１～第Ｕ番送信系列による干渉を除去した等化信号系列er_3（ｋ）及びその等化後のチャネル情報$e\alpha_3$（ｋ）と、第１～第Ｕ番送信系列中の第U_1＋１～第U_2番送信系列の第１～第U_1番送信系列及び第U_2～第Ｕ番送信系列による干渉を除去した等化信号系列er_4（ｋ）及びその等化後のチャネル情報$e\alpha_4$（ｋ）と、第１～第Ｕ送信系列中の第U_2＋１～第Ｕ送信系列の第１～第U_2送信系列による干渉を除去した等化信号系列er_5（ｋ）及びその等化後のチャネル情報$e\alpha_5$（ｋ）をそれぞれ出力する。

【０１０９】同様に第２段目の等化器８２－２では等化信号系列er_2（ｋ）とチャネル情報$e\alpha_2$（ｋ）が入力されて、等化信号系列er_6（ｋ）及び等化後のチャネル情報$e\alpha_6$（ｋ）と等化信号系列er_7（ｋ）及び等化後のチャネル情報$e\alpha_7$（ｋ）を出力する。Ｎ＝５の場合は第３段目の等化器８３－１～８３－５は図１８中のシングルユーザ等化器となる。あるいは、等化器８３－３の入力等化信号は２つの送信信号により構成され、等化器８３－３によりその２つの送信信号間の相互干渉を除去して２組の等化信号とその等化後のチャネル情報とを次のシングルユーザ等化器８４－１，８４－２でそれぞれ等化してもよい。更に、例えば等化器８３－４では等化信号er_6（ｋ）とチャネル情報$e\alpha_6$（ｋ）を入力して、その構成送信信号の全て、例えば３つの送信信号のそれぞれについて他の２つの送信信号との相互干渉と、それ自身のマルチパスによる符号間干渉を除去してもよい。第２段目の等化器８２－１，８２－２の１つ乃至複数で、複数の送信信号に対する各等化信号を一挙に得るように構成してもよい。

【０１１０】以上のように一般には第１段目の等化器から複数の等化信号系列と等化後チャネル情報の組を出力し、各等化信号系列及びその等化後のチャネル情報の組について、１乃至複数の等化器を１乃至複数段縦続させて、最終的には第１～第Ｎ番目の送信系列のそれぞれの等化出力、つまりこの例では対数尤度比Λ_1［b_n（ｋ）］を出力させることもできる。このように多段縦続等化処理を行う場合は、前述したように後段程、干渉除去するパス数Ｑの値を小として、演算処理量を少なくすることが好ましい。この場合は、前述したように、後段において減少したパスによる干渉成分を、その直前の等化段で除去するようにする。

【０１１１】以下において、図２１中の第１段目の等化器２１で、Ｎ個の送信系列、各送信系列のマルチパスの数がＱの受信信号からＵ個の送信系列の群の等化信号系列er_1（ｋ）及び等化後のチャネル情報$e\alpha_1$（ｋ）を得、その後段の等化器８２－１での等化処理では各送信列系のマルチパスの数をＱ′とする場合の等化処理を説明する。図１８及び図１９に示した実施例とほぼ同様に干渉ベクトル生成部７２で干渉ベクトル$\mathbf{B}'$（ｋ）を生成するが、この構成式（５３）、式（５４）が式（５３）、式（５４）′及び式（７３）に変更する。

【０１１２】

$$\mathbf{b}'(k+q)=[b'_1(k+q)\ b'_2(k+q)\cdots b'_n(k+q)\cdots b'_N(k+q)]^T : q=Q-1,\cdots 1 \qquad (53)$$

$$\mathbf{b}'(k+q)=[0\cdots 0\ \ b'_{U+1}(k+q)\cdots b'_N(k+q)]^T : q=0,\cdots,-Q'+1 \qquad (54)'$$

$$\mathbf{b}'(k+q)=[b'_1(k+q)\ b'_2(k+q)\cdots b'_n(k+q)\cdots b'_N(k+q)]^T : q=Q',\ \cdots,\ -Q+1 \qquad (73)$$

式（５４）′は第１～第Ｕ送信系列自体のシンボルと、Ｑ′のマルチパスに基づくこれら各系列の自身及び相互の符号間干渉成分を除いて等化するためのものであり、式（７３）は後段の等化でマルチパスの数をＱ′に減少するため、Ｑ′＋１番目乃至Ｑ番目のパスに基づく、第１～第Ｕ送信系列の自身及び相互の符号間干渉を除去するためのものである。

【０１１３】このようにして得られた干渉ベクトル $\mathbf{B}'(k)$ を用いて干渉信号レプリカ $\mathbf{H}\cdot\mathbf{B}'(k)$ を作り、これを受信ベクトル $\mathbf{y}(k)$ から引算し、つまり次式を計算する。

$$\mathbf{y}'_g(k)\equiv\mathbf{y}(k)-\mathbf{H}\cdot\mathbf{B}'(k) \qquad (27)''$$

$$=\mathbf{H}\cdot(\mathbf{B}(k)-\mathbf{B}'(k))+\mathbf{n}(k) \qquad (28)''$$

以下この干渉を引算する操作をソフト干渉キャンセルと呼ぶことにする。理想的に干渉信号のレプリカ $\mathbf{H}\cdot\mathbf{B}'(k)$ が作られているとすると、引算後得られる $\mathbf{y}'_g(k)$ は第１～第Ｕ送信系列のシンボル、$[b_n(k),\ b_n(k-1),\ \cdots,\ b_n(k-Q'+1)]$，$(n=1\sim U)$ の信号成分しか持ち得ないことが分かる。

【０１１４】次にソフト干渉キャンセル後の干渉余剰成分を前述と同様にＭＭＳＥ規範の線形フィルタで除去する。この場合の式（５５）と対応した式は次式（５５）′となる。

$$\mathbf{w}_g^H(k)\cdot\mathbf{y}'_g(k)\fallingdotseq\sum_{n=1}^{U}\sum_{q=0}^{Q'-1}\alpha_{nq}(k)\cdot b_n(k-q)=\boldsymbol{\alpha}_g^H(k)\cdot\mathbf{b}_g(k) \qquad (55)'$$

ここで、

$$\boldsymbol{\alpha}_g(k)=[\alpha_{1,0}(k),\ \cdots,\ \alpha_{1,Q'-1}(k),\ \cdots,\ \alpha_{U,0}(k),\ \cdots,\ \alpha_{U,Q'-1}(k)]^T \qquad (55-1)$$

$$\mathbf{b}_g(k)=[b_1(k),\ \cdots,\ b_1(k-Q'+1),\ \cdots,\ b_U(k),\ \cdots,\ b_U(k-Q'+1)]^T \qquad (55-2)$$

これら $\mathbf{w}_g(k)$，$\boldsymbol{\alpha}_g(k)$ を求めることも前述と同様に式（５６）を次式として右辺が最小となる $\mathbf{w}_g(k)$，$\boldsymbol{\alpha}_g(k)$ を求める。

【０１１５】

$$(\mathbf{w}_g(k),\ \boldsymbol{\alpha}_g(k))=\arg\min\|\mathbf{w}_g^H(k)\cdot\mathbf{y}'_g(k)-\boldsymbol{\alpha}_g^H(k)\cdot\mathbf{b}_g(k)\|^2 \qquad (56)'$$

$\alpha_{1,0}(k)=1$ を条件とする。付加された拘束条件は、$\boldsymbol{\alpha}_g(k)=0$，$\mathbf{w}_g(k)=0$ なる解を避ける為であり、$\|\boldsymbol{\alpha}_g(k)\|^2=1$ なる拘束条件で解く事も可能であるが以下では、$\alpha_{1,0}(k)=1$ の場合以下のように問題を置き換える。

$$\mathbf{m}_g(k)=\arg\min\|\mathbf{m}_g^H(k)\cdot\mathbf{z}_g(k)\|^2 \qquad (57)'$$

$\mathbf{m}_g^H(k)\cdot\mathbf{e}_{MQ'+1}=-1$ を条件とする。

ここで、

$$\mathbf{m}_g(k)\equiv[\mathbf{w}_g^T(k),\ -\boldsymbol{\alpha}_g^T(k)]^T \qquad (58)'$$

$$\mathbf{z}_g(k)\equiv[\mathbf{y}_g^T(k),\ \mathbf{b}(k)_g^T]^T \qquad (59)'$$

$$\mathbf{e}_{MQ'+1}=[0\ \cdots\ 1\ \cdots\ 0]^T \qquad (60)'$$

（$\mathbf{e}_{MQ'+1}$ 中の１の要素はＭＱ′＋１番目）

前記文献［２］に示されているラグランジェ未定係数法よりこの最適化問題の解は以下で与えられる。

【０１１６】

$$\mathbf{m}_g(k)=-\mathbf{R}_{zz}^{-1}\cdot\mathbf{e}_{MQ'+1}/(\mathbf{e}_{MQ'+1}^H\cdot\mathbf{R}_{zz}^{-1}\cdot\mathbf{e}_{MQ'+1}) \qquad (61)'$$

ここで、

【０１１７】

【数２５】

$$R_{zz}=E[Z_g(k)\cdot Z_g^H(k)] \qquad (62)'$$

$$=E\begin{bmatrix}H\cdot\Lambda(k)\cdot H^H+\sigma^2 I & H_g^H\\ H_g & I\end{bmatrix} \qquad (63)'$$

【０１１８】

$$\Lambda_n(k)=\mathrm{diag}[\mathbf{D}_n(k+Q-1),\ \cdots,\ \mathbf{D}_n(k),\ \cdots,\ \mathbf{D}_n(k-Q+1)] \qquad (64)'$$

【０１１９】

【数２６】

$$H_g=\begin{bmatrix} h_1(Q-1) & 0 & 0 & \cdots & h_U(Q-1) & 0 & 0 \\ h_1(Q-2) & \ddots & 0 & \cdots & h_U(Q-2) & \ddots & 0 \\ h_1(Q-3) & \vdots & h_1(Q-1) & \cdots & h_U(Q-3) & \vdots & h_U(Q-1) \\ \vdots & \vdots & \vdots & \cdots & \vdots & \vdots & \vdots \\ h_1(0) & \cdots & h_1(Q'-1) & \cdots & h_U(0) & \cdots & h_U(Q'-1) \end{bmatrix} \quad (65)'$$

【０１２０】

$D_n(k+q)=\mathrm{diag}[1-b'_1{}^2(k+q),\cdots,1-b'_n{}^2(k+q),\cdots,1-b'_N{}^2(k+q)]\ :q=Q+1,\cdots,1$　（６６）

$D_n(k+q)=\mathrm{diag}[1,\cdots,1,1-b'_{U+1}{}^2(k+q),\cdots,1-b'_N{}^2(k+q)]\ :q=0,\cdots,-Q'+1$　（６７）′

$D_n(k+q)=\mathrm{diag}[1-b'_1{}^2(k+q),\cdots,1-b'_n{}^2(k+q),\cdots,1-b'_N{}^2(k+q)]\ :q=Q',\cdots-Q+1$　（７４）

つまりチャネルパラメータが既知であれば、$m_g(k)$は式（６１）′で求めることができる。更に式（５８）′に従い$w_g(k)$，$\alpha_g(k)$（$=e\alpha_1(k)$）も求められる。このような計算を例えば図１９中のフィルタ特性推定部７６で行い、フィルタ処理部７７－１で次式を計算してフィルタ処理する。

【０１２１】

$er_1(k)=w_g{}^H(k)\cdot y'_g(k)$

この等化出力$er_1(k)$と等化後チャネル情報$e\alpha_1(k)=\alpha_g(k)$が後段の等化器８２－１に送られる。以上のようにして例えば５の送信系列（ユーザ）時に３送信系列（ユーザ）グループと２送信系列（ユーザ）グループとに分ける場合は、Ｕ＝３及び２で上記アルゴリズムを実行し、これら二つの等化出力$er_1(k)$、$e\alpha_1(k)$と$er_2(k)$，$e\alpha_2(k)$を後続の３送信系列（ユーザ）用及び２送信系列（ユーザ）用の等化器に入力してそれぞれ各送信系列（ユーザ）の等化出力を得る。

【０１２２】また前述した検出する信号の誤り訂正復号結果を軟判定送信シンボルに反映させることは、図８に示したシングルユーザターボイコライザ受信機、図９に示したＲＡＫＥ合成処理ターボ受信機、図１０に示したアダプティブアレーアンテナ受信部を備えるターボ受信機、更に一般に図１２に示したチャネル推定器４２を備えるターボ受信機にも適用できる。更に図１３、図１４及び図１５ではチャネル行列Hと共分散行列Ｕ＾の、２回目以後の推定に確からしいと判断されたシンボル硬判定値も参照信号として利用したが、２回目以後もユニークワードのみを参照信号として式（５１）を利用して共分散行列Ｕ＾の推定を行い、シンボル硬判定値を用いるチャネル推定及び共分散行列Ｕ＾の推定は省略してもよい。

第１発明（２）（並列送信）

次に１人の利用者による情報系列ｃ（ｉ）を複数の並列系列として送信することにより周波数利用効率よく高速伝送を行うことが提案されている。このような送信信号に対し、この発明を適用したターボ受信機の実施例を説明する。

【０１２３】図２２に図１と対応する部分に同一参照符号を付けて示すよう送信側において、変調器１３よりの変調出力信号ｂ（ｊ）は直列－並列変換器１４によりＮ個の系列に各シンボルｂ（ｊ）が順次分配され、２以上の整数Ｎ個の系列信号$b_1(k),\cdots,b_N(k)$とされ、図に示していないが、これらは無線周波数の信号に変換された後、Ｎ個のアンテナから送信される。これらＮ個の系列信号はチャネル（伝送路）を通じて、この発明のターボ受信機に受信される。この受信機の受信アンテナは１個以上であり、この受信信号は１以上の整数Ｍ個のベースバンドデジタル受信信号$r_m(k)$（$m=1,2,\cdots,M$）として多出力等化器３１に入力される。受信信号$r_m(k)$は例えば図２８に示したように生成される。

【０１２４】多出力等化器３１は図２に示した構成と同様であり、図３に示した処理手順と同様な処理を行う。その際に、図２２中に示した復号器２４よりの対数尤度比$\Lambda_2[b(i)]$から外部情報$\lambda_1[bi]$が減算器２５で減算され、その減算出力がインタリーバ２６によりインタリーブされて事前情報$\lambda_2[b(j)]$とされ、その事前情報$\lambda_2[b(j)]$が直列－並列変換器１５でＮ系列の事前情報$\lambda_2[b_1(k)],\cdots,\lambda_2[b_N(k)]$に変換されて多出力等化器３１へ入力される。

【０１２５】よって多出力等化器３１ではそのＭ系列の受信信号が、先に述べたと同様に線形等化処理されて、Ｎ個の対数尤度比系列$\Lambda_1[b_1(k)],\cdots,\Lambda_1[b_N(k)]$が出力される。このＮ個系列の対数尤度比系列は並列－直列変換器１６により１系列の対数尤度比系列$\Lambda_1[b(j)]$に変換されて、減算器２２へ供給される。この構成によれば多出力等化器３１の入力信号形式が、図１乃至図３で説明したものと同様になり、従って図１乃至図３を参照して行った等化処理により、Ｎ系列の対数尤度比$\Lambda_1[b_1(k)],\cdots,\Lambda_1$

［b_N （ｋ）］を得ることができ、直列－並列変換器１５と並列直列変換器１６とを用いることによって繰り返し復号処理を行うことができることは容易に理解されよう。図１乃至図３においてｎ番目の送信機の送信信号と対応してこの場合はＮ個の並列送信信号中のｎ番目（ｎ列目）の送信信号が等化されることになる。またこのＮ系列信号の並列送信に対する受信について、図４乃至図７を参照した実施例を適用できることも容易に理解できよう。また図１８乃至図２１に示した複数の等化段による縦続的処理により、図１乃至図３１に示した単一の等化段による処理に比べ受信特性は向上する。

【０１２６】この発明のターボ受信方法、受信機は畳み込み符号／ターボ符号＋インタリーバ＋多値変調（ＱＰＳＫ，８ＰＳＫ，１６ＱＡＭ，６４ＱＡＭなど）、ＴＣＭ（Trellis Coded Modulation）／ターボＴＣＭなどに対する受信にも適用できる。

M個の受信信号の生成

上述ではＭ個の受信信号r_1（ｋ），…，r_M（ｋ）を、Ｍ個のアンテナ＃１，…，＃Ｍから求めたが、１個のアンテナから求めてもよく、あるいは、２以上の整数Ｌ個のアンテナの受信信号からＬより多いＭ個の受信信号を求めてもよい。図１において特に示さなかったが各アンテナ＃１，…，＃Ｍからの受信信号はベースバンド変換部によりベースバンドの受信信号r_1，…，r_mとされ、サンプリングされて離散時刻ｋのディジタル信号r_1（ｋ），…，r_M（ｋ）とされている。

【０１２７】例えば図３０Ｂに示すようにＬ＝２個のアンテナ＃１，＃２で受信された受信信号はそれぞれベースバンド変換部６１－１，６１－２でそれぞれベースバンド信号に変換され、ベースバンド変換部６１－１と６１－２の各出力はサンプリング信号発生器６２からのサンプリング信号と、このサンプリング信号を移相器６３でその周期ＴのＴ／２だけ位相をずらしたサンプリング信号とにより、それぞれＡ／Ｄ変換器６４－１，６４－２と６４－３，６４－４でサンプリングされてディジタル信号r_1（ｋ），r_2（ｋ）とr_3（ｋ），r_4（ｋ）に変換され、図１又は図１８あるいは図２２に示したターボ受信機３０に入力され、Ｎ個の復号出力を得るようにしてもよい。なおターボ受信機３０に入力される受信信号r_1（ｋ），…，r_4（ｋ）の各サンプリング周期は、１個のアンテナごとに１個の受信信号r_m（ｋ）を受信する場合のサンプリング周期と一致するようにサンプリング信号発生器６２よりのサンプリング信号の周波数が選定される。

【０１２８】

【発明の効果】以上述べたようにこの第１発明（１）によれば、多出力（ＭＩＭＯ）受信方法を実現できる。定量的な効果として誤り率特性を図２３、図２４に示す。各図において横軸のE_b／N_oはビットエネルギ対ノイズ比である。シュミレーション条件として以下を想定した。

ユーザ（送信機）数Ｎ	２
各ユーザのマルチパス数Ｑ	５
受信アンテナ数	２本
１フレーム内の情報シンボル数	４５０ビット
１フレーム内のユニークワード数	２５ビット
チャネル推定法	ＲＬＳ（忘却係数０．９９）
誤り訂正符号	レート１／２，拘束長３畳み込み符号
ドップラ周波数	１０００Ｈｚ（レイリーフェージング）
変調方式	ＢＰＳＫ
伝送速度	２０Ｍｂｐｓ
復号器２４	Ｍａｘ－Ｌｏｇ－Ｍａｐデコーダ
繰り返し数	４回
フレーム内でフェージングなし	

なおフィルタ係数$\mathbf{w}$の計算には前記逆行列の補助定理による近似は用いなかった。

【０１２９】図２３は、チャネル推定が完全に行われた（推定誤差はなし）、つまりチャネルは既知であると仮定した時の誤り率特性であり、ユーザ（送信機）数Ｎ＝２、受信アンテナ数Ｍ＝２、Ｒａｙｌｅｇｈパス数Ｑ＝５の場合である。繰り返し１回目は繰り返ししていない状態であり，繰り返し２回目で１回繰り返しを行った結果である。繰り返しにより誤り率特性が大幅に改善されていることが分かる。これによりこの発明のＭＩＭＯ用ターボ受信方法は適切に動作することが分かる。

【０１３０】図２４は繰り返しチャネル推定（第４発明）の効果を示す。横軸はしきい値Ｔｈである。E_b／N_o＝４ｄＢに固定し（E_bは1ユーザ分である）、Ｔｈ＝１．０は１つもシンボル硬判定値が選ばれない、つまりシンボル硬判定値を用いるチャネル推定が行われない従来法と考えられる。この場合は図から明らかなようにチャネル推定が不正確なためＢＥＲ特性の繰り返し効果は少ない。しきい値Ｔｈ＝０は、硬判定値をそのまま全部用いる場合であり、このように情報シンボルの硬判定値も利用すると図から明らかなように平均ビット誤り率が改善され、それだけチャネル推定が正確に行うこと

ができることが理解される。更にしきい値Ｔｈ＝０．２～０．６程度ではＴｈ＝０の場合より平均ビット誤り率が小となっており、つまり確からしい硬判定値のみを利用した方が良いことがわかる。特にＴｈ＝０．２５付近が最も好ましいことも理解される。

【０１３１】図２５に、しきい値により確からしい送信シンボル硬判定値をチャネル推定に用いる、つまり繰り返しチャネル推定を用いたＭＩＭＯ受信方法の誤り率特性を曲線６６として示す、この場合のしきい値は０．２５に設定し、結果は繰り返し４回後の特性であり、Ｎ＝２、Ｍ＝２、Ｑ＝５Ｒａｙｌｅｇｈ、$f_d T_s$＝１／２００００，９００シンボル／フレームである。比較のためチャネル推定が完全な場合の誤り率特性を曲線６７に、従来の情報シンボルの硬判定値はチャネル推定に利用しない、つまり繰り返しなしのチャネル推定（チャネル推定は１回だけ）を用いたときの誤り率特性を曲線６８に示す。このグラフよりチャネルの繰り返し推定を用いた場合、誤り率特性はチャネル推定完全の場合のそれに近づいていることが分かる。

【０１３２】また上述したチャネル推定方法によれば、復号された軟判定値から、その硬判定値の確からしいか否かを判定し、確からしい硬判定値のシンボル情報をも、次回の繰り返し受信処理の際のチャネル推定に利用することにより、チャネル推定をより正しく行うことができ、復号品質を向上することができる。次に共分散行列Ｕ^（ガウス性雑音以外の雑音）を推定するようにした実施例の効果を確認するため以下の条件でシミュレーションを行った。

全ユーザ（送信機）数Ｎ	３（うち１ユーザを未知干渉：ｉ（ｋ）とする）
各ユーザのマルチパス数Ｑ	５
受信アンテナ数	３本
１フレーム内の情報シンボル数	４５０ビット
誤り訂正符号	レート１／２，拘束長３畳み込み符号
ドップラー周波数	１０００Ｈｚ
変調方式	ＢＰＳＫ
伝送速度	２０Ｍｂｐｓ
復号器２４	Ｌｏｇ－ＭＡＰはデコーダ
繰り返し数	４回

３ユーザ（送信機）は等電力とした。図２６は図１４、図１５、図１６に示したＨ、Ｕ^を推定するターボ受信機のＢＥＲ（ビット誤り率）特性のシミュレーション結果、図２７は図１に示したターボ受信機（図１３の方法を用いる受信機）をそのまま用いたＢＥＲ特性を示す。図２６では、雑音は白色性ガウス雑音のみとしており、チャネル推定、復号処理を２回以上繰り返してもその効果がほとんど得られていないが、図２７では繰り返し数を多くすることによりＢＥＲ特性の向上が達成され、しかも、同一Ｅｂ／Ｎｏに対し、ＢＥＲが図２６に示すものよりも可成り小さい値を示すことが理解される。

【０１３３】次に目的とするユーザ（送信機）よりの受信信号のシンボル軟判定値$b'_n(k)$に対し誤り訂正復号結果を反映させた実施例（第２発明）の効果を確認するために以下の条件でシミュレーションを行った。

全ユーザ（送信機）数Ｎ	４
各ユーザのマルチパス数Ｑ	５
受信アンテナ数Ｍ	２
１フレーム内の情報シンボル数	９００
誤り訂正符号	畳み込み符号（符号化率：1/2 、拘束長３）
変調方式	ＢＰＳＫ
復号器	Ｌｏｇ－Ｍａｐデコーダ
誤り符号化率	１／２
繰り返し数	５

また$f(b'_n(k))=\alpha\times b'_n(k)$

とした。

【０１３４】図２８は、図１に示した多出力ターボ受信機と、$b'_n(k)$に誤り訂正復号結果を反映させた多入力多出力ターボ受信機のＢＥＲ特性を前者はプロット点を黒で、後者は白でそれぞれ示す。丸は繰り返し１回目、下向き三角は繰り返し２回目、菱形は繰り返し３回目、左向き三角は繰り返し４回目、右向き三角は繰り返し５回目を表わす。図２８Ａはα＝０．２に固定したときのＥｂ／Ｎｏに対するＢＥＲ特性のシミュレーション結果、図２６ＢはＥｂ／Ｎｏ＝６ｄＢとしたときのαに対するＢＥＲ特性のシミュレーション結果をそれぞれ示す。ここでα＝０の場合は$b'_n(k)$＝０とした場合に等しい。この図２８Ａより、$b'_n(k)$に誤り訂正復号結果を反映させた多入力多出力受信機では、図１に示した多入力多出力ターボ受信機に比べ、繰り返し回数が３回目以降の場合において１回前の繰り返し復号時の

ＢＥＲに対して改善効果が大きく、繰り返し回数が３回目以降ではＢＥＲ＞10^{-4}の範囲において各ＢＥＲを達成する所要E_b/N_0で比較した場合、$b'_n(k)$に誤り訂正復号結果を反映させた多入力多出力ターボ受信機は図１に示した多入力多出力ターボ受信機に比べ約０．５ｄＢ以上の利得が得られている。また、E_b/N_o＝６ｄＢの繰り返し５回目において、ＢＥＲ＝10^{-5}ＢＥＲを達成しており、図１に示したものに比べＢＥＲを１／１０以下に低減できていることが分かる。この図２８Ｂより、αの値としては０＜α＜０．６の範囲で改善が得られており、αを０．６より大きくすると逆にＢＥＲ特性が劣化してしまい、正しい復号結果が得られなくなる。この結果より、この場合のαの最適値は０．２であることが分かる。しかしながら、αの値は前記最適値に限るものではなく、特に受信するユーザの数、干渉を含む伝搬環境、受信するアンテナの数などによって、改善効果を有するαの適正範囲が変更されてもよく、また最適値αの値も他の値を取っても良い。

【０１３５】ユーザ（送信機）の数をＮ、各送信機のマルチパスの数をＱ、受信機のアンテナの数をＭとし、ＢＰＳＫ変調の場合は、従来のシングルユーザのターボ受信機をそのまま多出力（ＭＩＭＯ）に拡張した場合の等化器における計算量は先に述べたように$2^{N(Q-1)}$のオーダであるが、第３発明のターボ受信方法によればＮ（ＭＱ）^{3}のオーダで済む。例えばＮ＝８、Ｑ＝２０、Ｍ＝８とすると$2^{N(Q-1)}$≒５×10^{45}であるがＮ（ＭＱ）^{3}≒３７・10^7となり、この第２発明のターボ受信方法によれば計算量を著しく低減することができる。

【０１３６】この第３発明のターボ受信方法によれば良好なビット誤り率特性が得られることを以下の条件でシミュレーションを行って確認した。チャネル行列 $\mathbf{H}$ は既知とした。

ユーザー数Ｎ	４
各ユーザのマルチパス数Ｑ	５
受信アンテナ数Ｍ	２本
１フレーム内の情報シンボル数	９００ビット
誤り訂正符号	レート１／２、拘束長３畳み込み符号
ドップラー周波数	1000Ｈｚ（レイリーフェージング）
変調方式	ＢＰＳＫ
伝送速度	２０Ｍｂｐｓ
復号器	Ｌｏｇ－ＭＡＰデコーダ
繰り返し数	６回
チャネル推定は理想	

図２９にこのＢＥＲ（ビット誤り率）特性のシミュレーション結果を示す。横軸は平均E_b（ビットエネルギー）／N_o（雑音電力）であり、f_dはドップラー周波数、T_sは送信シンボル周期である。このグラフに示されているＭＲＣはオーダ１０（２アンテナ×５パス）ダイバーシチチャネルにおける最大比合成（Maximal Ratio Conbining ：ＭＲＣ）後の信号をビタビ復号した際に得られるＢＥＲ特性であり、等化器が完全に干渉をキャンセルした際のＢＥＲ特性に対応する。つまり繰り返し後のＢＥＲがＭＲＣカーブにどれだけ近いかで受信器の品質を評価することができる。図２７により、この第２発明のターボ受信方法によればE_b/N_oが高くなる程ＢＥＲが減少し、かつ繰り返し回数を多くすればＢＥＲ特性はＭＲＣのＢＥＲ特性に近づき、特に繰り返し回数６ではＭＲＣに非常に近づくことが分かる。つまり、この第３発明のターボ受信方法による多出力ターボ受信機は４ユーザ、各５パス、２受信アンテナという厳しい条件でも適切に動作することが確認された。

【図面の簡単な説明】

【図１】この第１発明のターボ受信機の実施例を含むシステムの機能構成を示す図。

【図２】図１中の多出力等化器３１の具体的機能構成例を示す図。

【図３】この第１発明のターボ受信方法の実施例を示す流れ図。

【図４】Ａはフレーム構成例を示す図、Ｂは第４発明における繰り返しチャネル推定法を説明するための、各繰り返しにおける処理を示す図である。

【図５】確からしい硬判定シンボルを取り出すための機能構成例を示す図。

【図６】この発明における繰り返しチャネル推定の処理手順の例を示す流れ図。

【図７】Ａは検出する信号の誤り訂正復号結果を反映させる第２発明における等化器３１の一部の機能構成例を示す図、Ｂはその処理手順の例を示す図である。

【図８】ターボイコライザを繰り返し行う受信機の例を示す図。

【図９】ＲＡＫＥ受信－ターボ復号の繰り返しを行う受信機の例を示す図。

【図１０】アダプティブアレーアンテナ受信－ターボ後の繰り返しを行う受信機の例を示す図。

【図１１】ターボイコライザ及びターボデコーダの概略を示す図。

【図１２】受信信号に対し、推定チャネルを用いる処理と、その処理された信号の復号処理とを繰り返す受信機の概略を示す図。

【図１３】受信信号に対し、推定チャネルを用いる処理とその処理された信号の復号処理とを繰返す受信方法の概略の処理手順の例を示す流れ図。

【図１４】Ａはフレーム構成例を示す図、Ｂは受信信号に白色性ガウス雑音以外の雑音を含む場合の、チャネルＨと雑音共分散行列Ｕの推定の繰り返し処理を示す図である。

【図１５】雑音共分散行列Ｕの推定を用いる等化器の一部の機能構成例を示す図。

【図１６】雑音共分散行列Ｕの推定を用いるチャネル値推定と、復号処理を繰り返す処理手順の例を示す流れ図。

【図１７】この第３発明によるターボ受信機の原理を示す図。

【図１８】この第３発明によるターボ受信機の機能構成例を示す図。

【図１９】図１８中のマルチユーザ（前段）等化器７１の機能構成の具体例を示す図。

【図２０】この第３発明によるターボ受信方法の処理手順の例を示す流れ図。

【図２１】第３発明における多段等化部分の他の機能構成例を示す図。

【図２２】第１発明（２）の実施例が適用されたシステム構成例を示す図。

【図２３】第１発明（１）を適用したターボ受信機の誤り率特性図（チャネルは完全に推定されたと仮定し、Ｅｂ（ビットエネルギー）：２ユーザ分N_0は雑音エネルギー）。

【図２４】しきい値（Ｔｈ）を変化させて繰り返しチャネル推定を行った場合の誤り率特性を示す図。

【図２５】第４発明において、特に繰り返しチャネル推定を用いたターボ受信機の誤り率特性図。

【図２６】雑音共分散行列Ｕの推定を用いるターボ受信機の誤り率特性を示す図。

【図２７】図１に示したターボ受信機の誤り率特性を示す図。

【図２８】検出する信号の誤り訂正復号結果を反映させた第２発明の実施例の誤り率特性を示す図。

【図２９】この第３発明のターボ受信機の誤り率特性のシミュレーション結果を示す図。

【図３０】ＭＩＭＯシステムの概念を示す図。

【図３１】従来のシングルユーザ用ターボ送受信機の機能構成を示す図。

【図１】

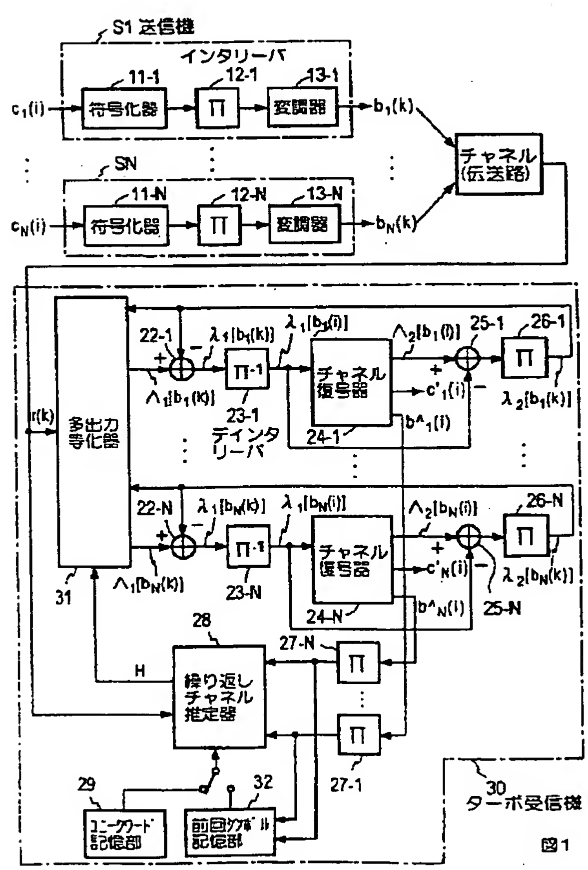


図1

【図２】

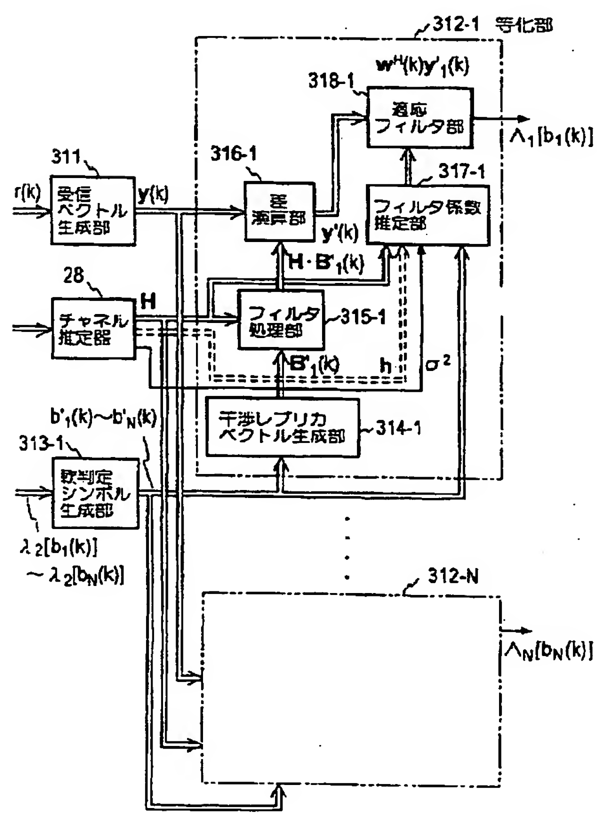


図2

【図３】

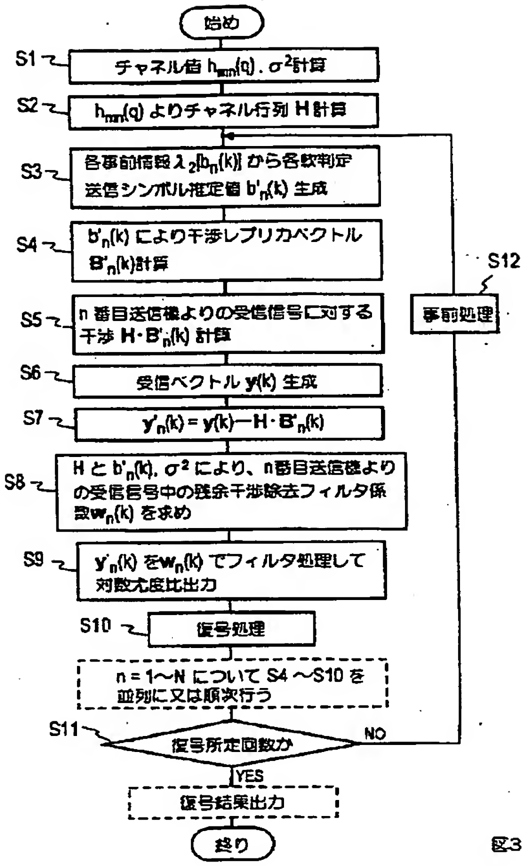


図3

【図４】

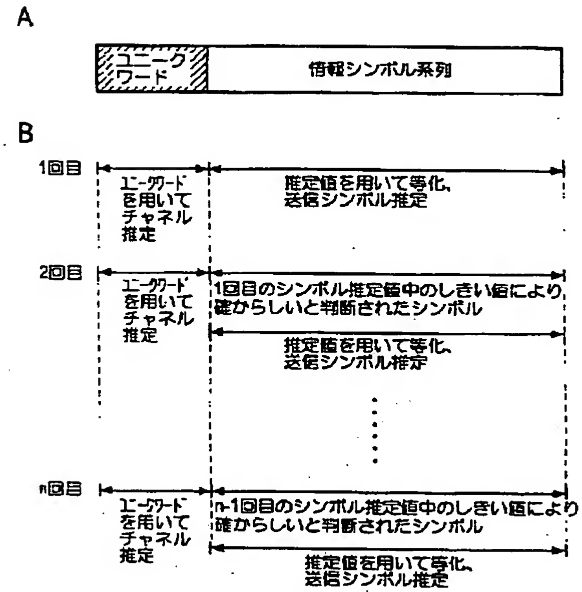


図4

【図５】

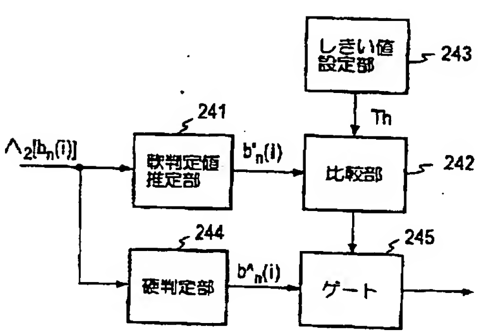


図5

【図６】

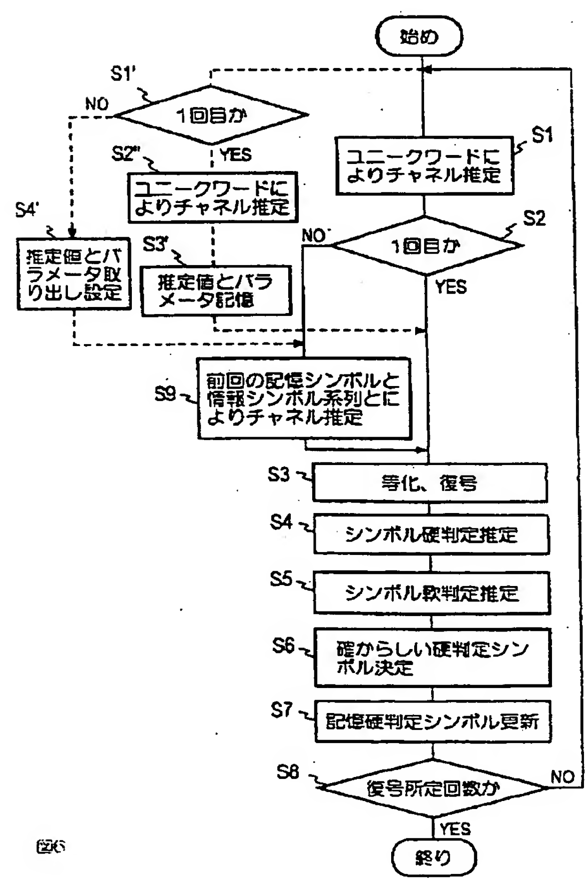


図6

【図７】

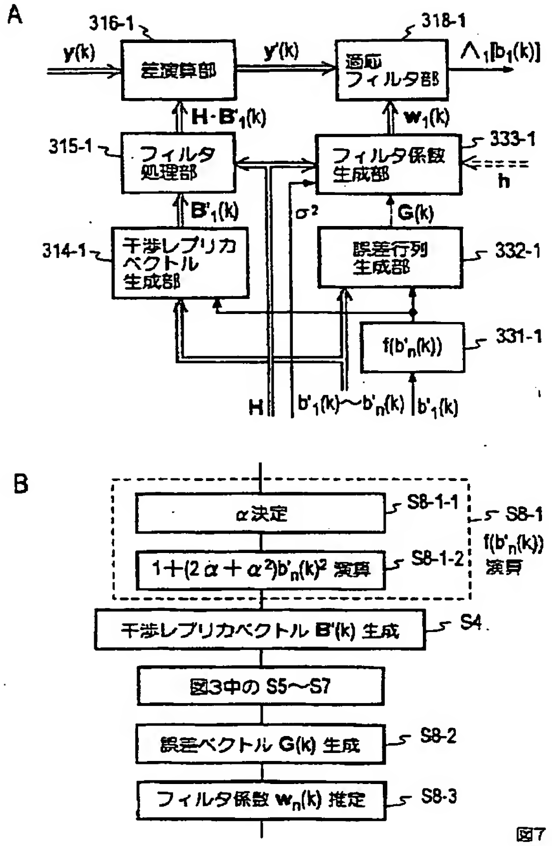


図7

【図８】

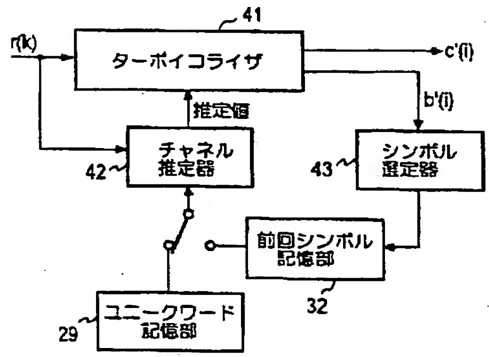


図8

【図１０】

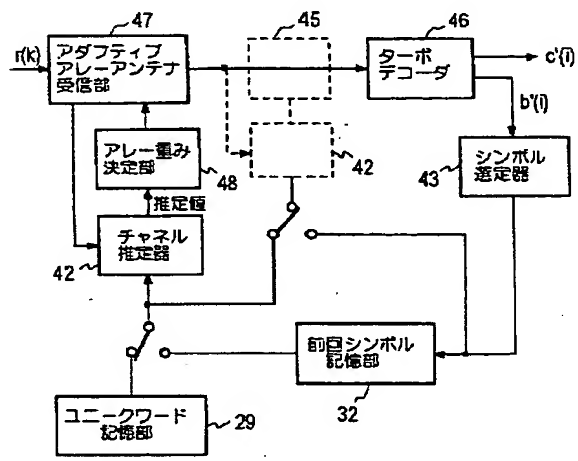


図10

【図９】

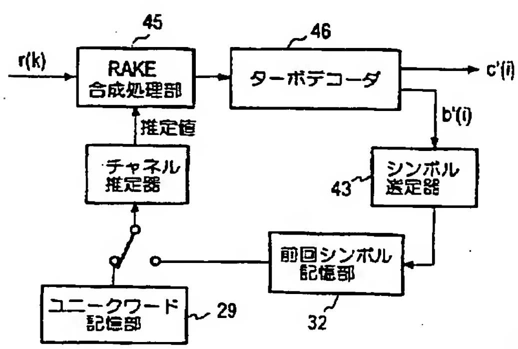


図9

【図１１】

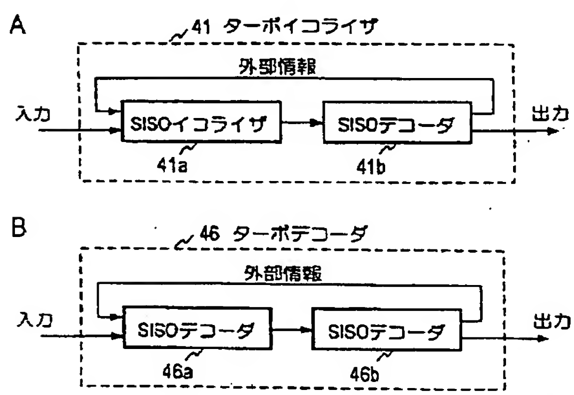


図11

【図１２】

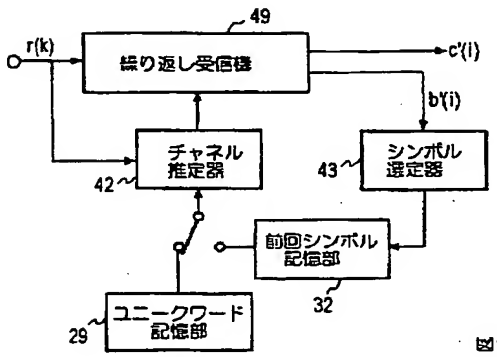


図12

【図１３】

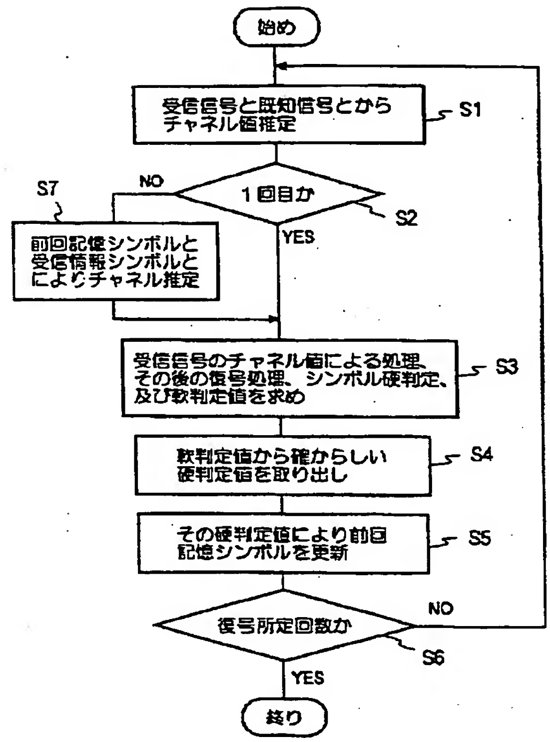


図13

【図１５】

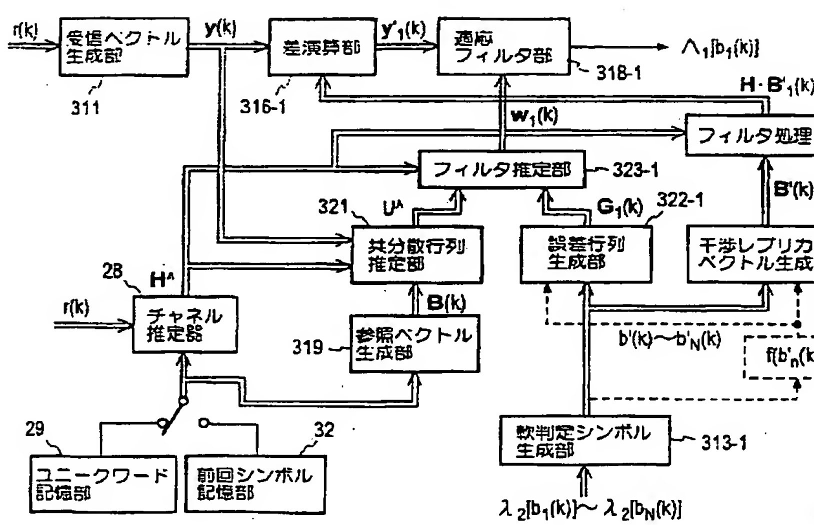


図15

【図１７】

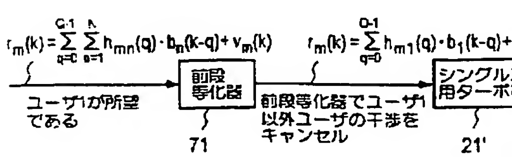


図１７

【図１４】

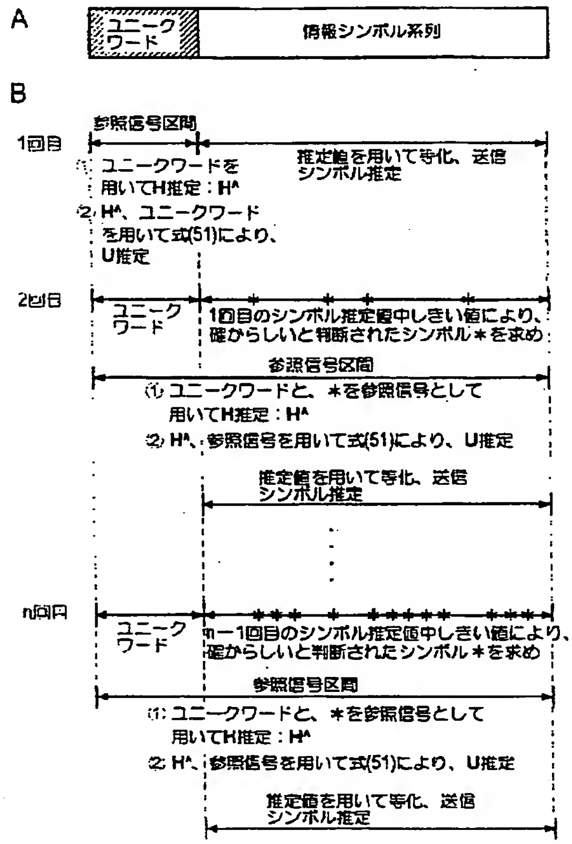


図14

【図１６】

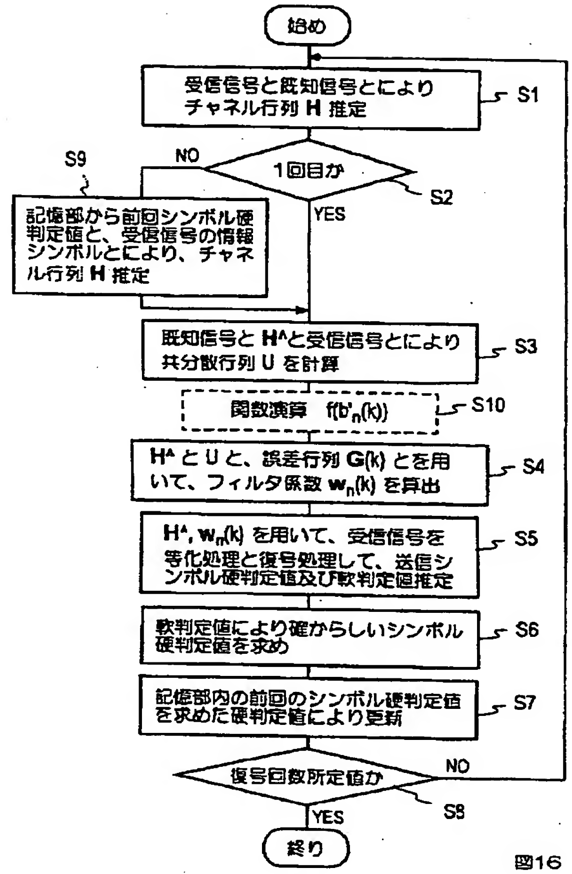


図16

【図１８】

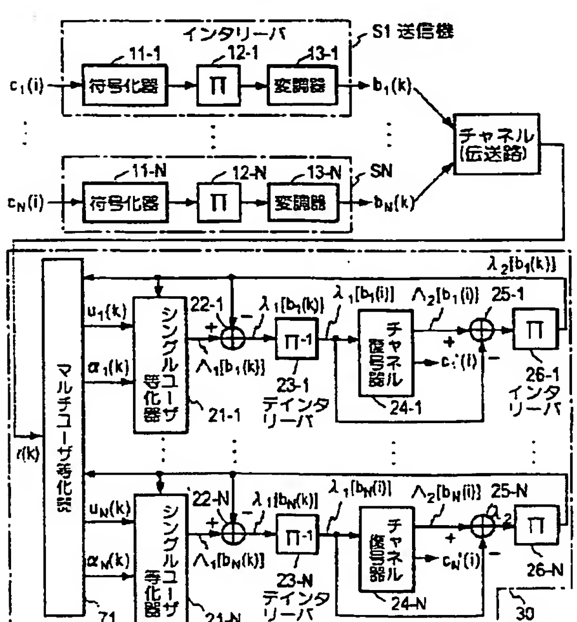


図１８

【図２６】

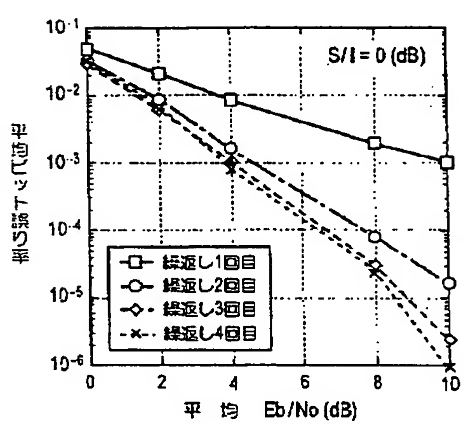


図26

【図１９】

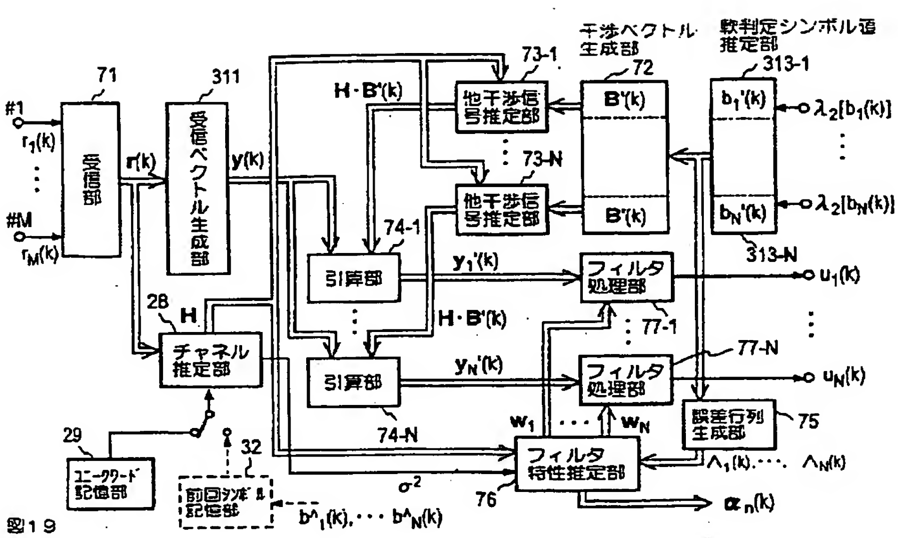


図１９

【図２０】

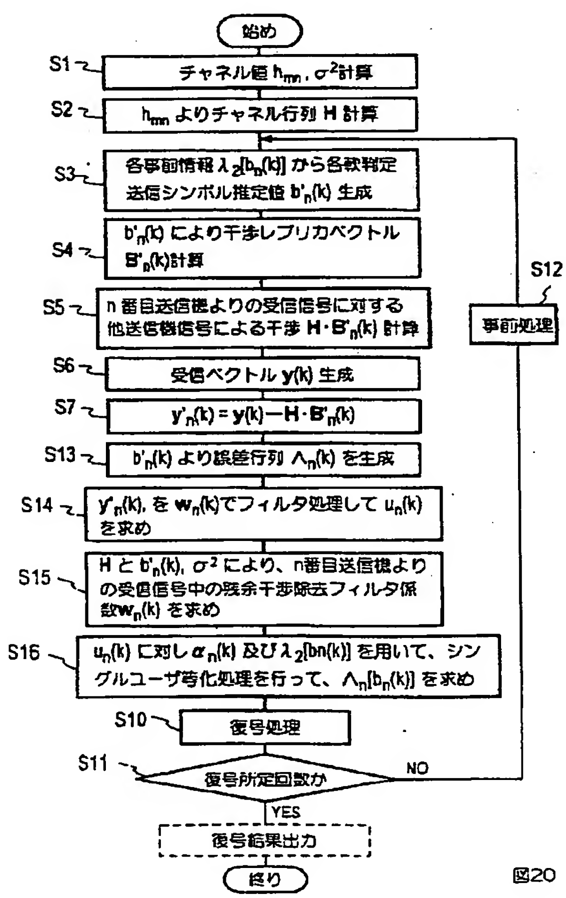


図20

【図２３】

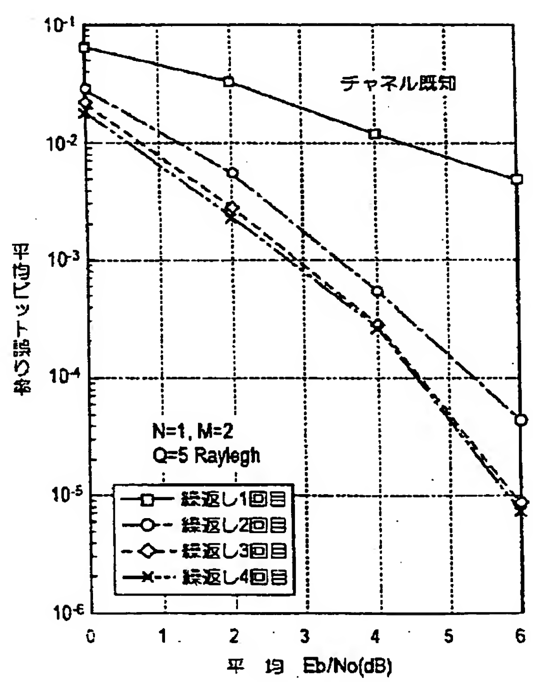


図23

【図２１】

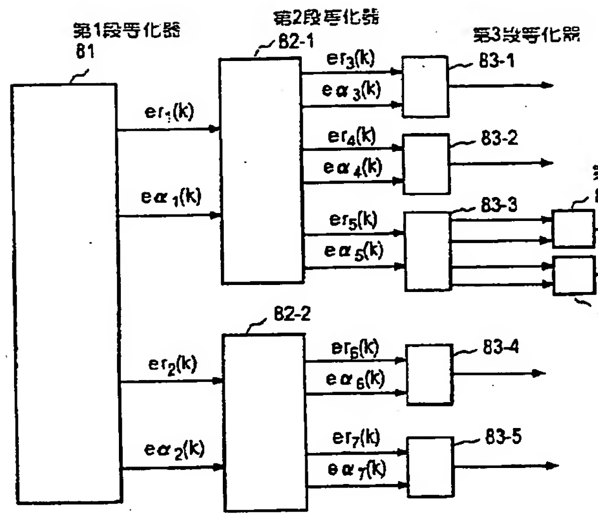


図２１

【図２７】

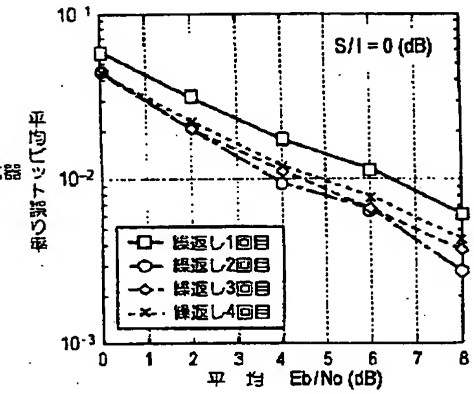
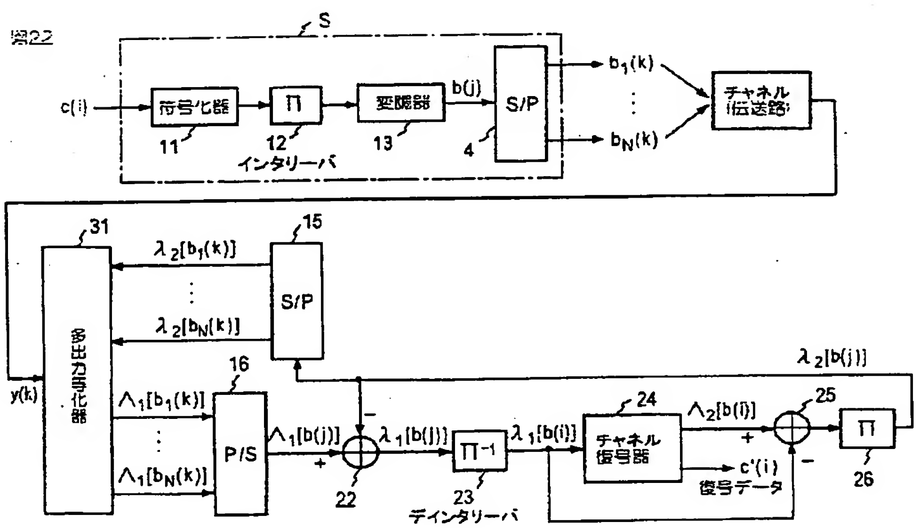


図27

【図２２】

図22



【図２４】

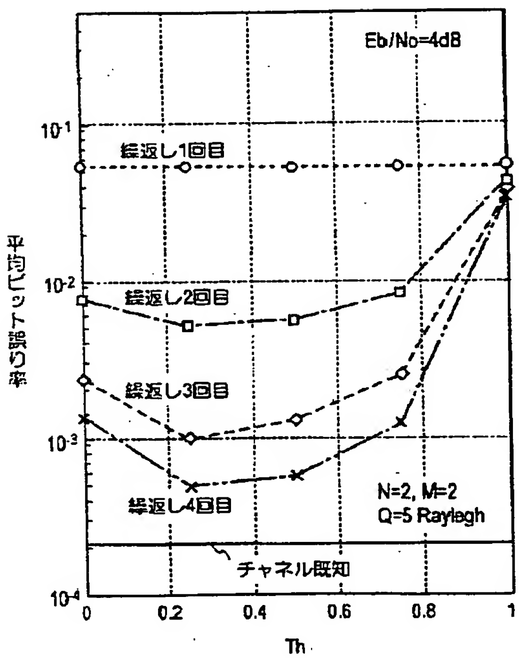


図24

【図２５】

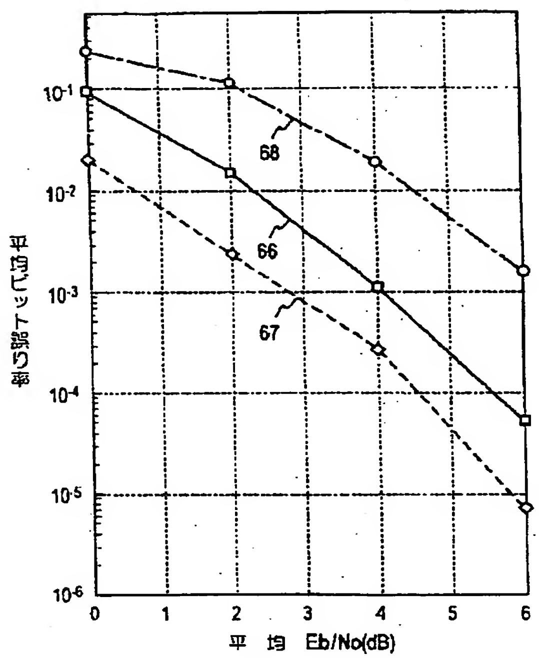


図25

【図２８】

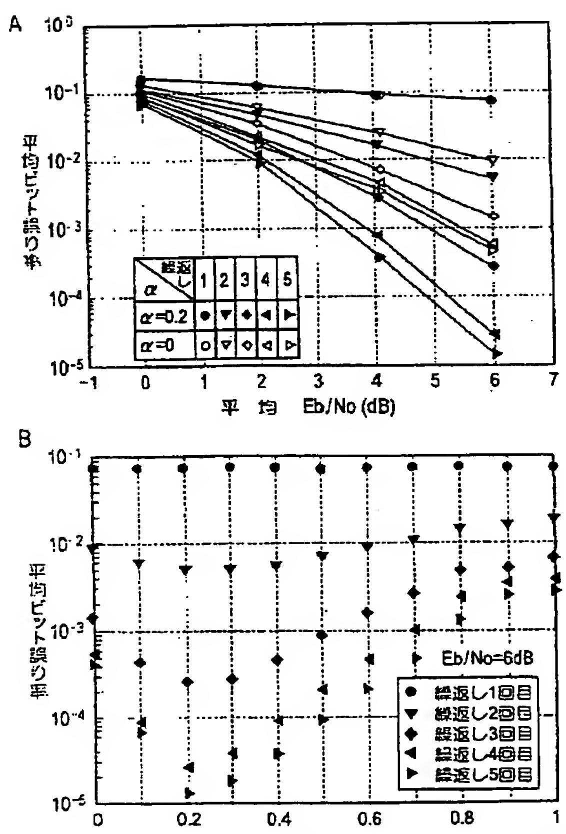


図28

【図２９】

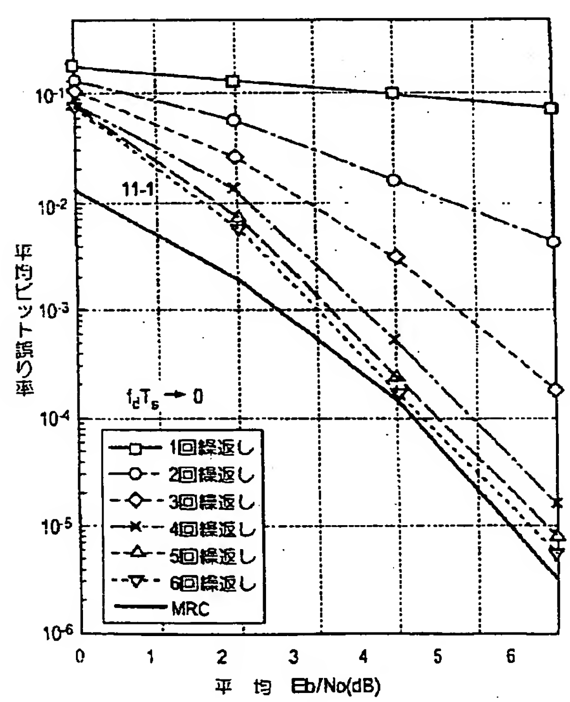


図29

【図３０】

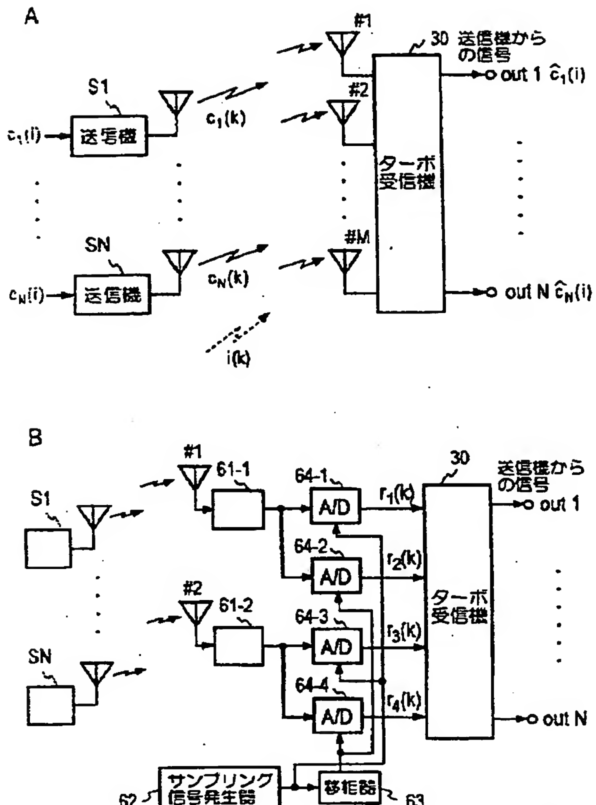


図30

【図３１】

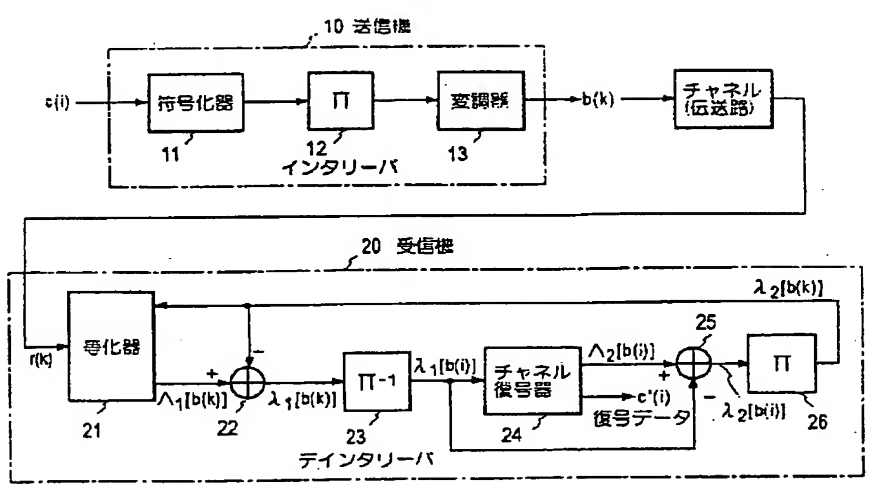


図31

【手続補正書】
【提出日】平成１４年３月１８日（２００２．３．１８）
【手続補正１】
【補正対象書類名】明細書
【補正対象項目名】請求項２
【補正方法】変更
【補正内容】
【請求項２】　受信ベクトル $\mathbf{y}$（ｋ）中の雑音成分の共分散行列をＵとして、軟判定送信シンボルｂ′$_n$（ｋ）、上記チャネル行列 $\mathbf{H}$ と、を用いて、上記適応フィルタ $\mathbf{w}_n$（ｋ）を

$$\mathbf{w}_n(k)=(\mathbf{H}\,\mathbf{G}(k)\,\mathbf{H}^H+U)^{-1}\mathbf{h}$$

ここで、

$$\mathbf{G}(k)=\mathrm{diag}[\mathbf{D}(k+Q-1)\cdots\mathbf{D}(k)\cdots\mathbf{D}(k-Q+1)]$$

$$\mathbf{D}(k+q)=\mathrm{diag}[1-b'^2_1(k+q),\cdots,1-b'^2_n(k+q),\cdots,1-b'^2_N(k+q)]\quad q=Q-1\cdots-Q+1,\ q\neq0\text{で、}$$

$$=\mathrm{diag}[1-b'^2_1(k+q),\cdots,1,\cdots,1-b'_N{}^2(k+q)]\quad q=0\text{で、}$$

【数２】

$$\mathbf{h}=\begin{bmatrix}H_{1,(Q-1)\cdot N+n}\\H_{2,(Q-1)\cdot N+n}\\\vdots\\H_{M,(Q-1)\cdot N+n}\end{bmatrix}$$

$\mathbf{H}_{1,(Q-1)\cdot N+n}$ は上記行列 $\mathbf{H}$ の１行（Ｑ－１）Ｎ＋ｎ列成分により算出することを特徴とする請求項１記載のターボ受信方法。
【手続補正２】
【補正対象書類名】明細書
【補正対象項目名】請求項３
【補正方法】変更
【補正内容】
【請求項３】　２以上の整数Ｎ個の送信機からの信号を受信するターボ受信方法であって、
１以上の整数Ｍ個の受信信号ｒ$_m$ と、既知信号とから、チャネル値ｈ$_{mn}$（ｑ）及びチャネル行列 $\mathbf{H}$ を計算し、ここでm＝１，…，Ｍ、ｎ＝１，…，Ｎ、ｑ＝０，…，Ｑ－１、Ｑは各送信電波のマルチパスの数
Ｎ個の事前情報λ$_2$［ｂ$_n$（ｋ）］から軟判定送信シンボルｂ′$_n$（ｋ）を求め、ここでｋは離散的時刻、
チャネル値ｈ$_{mn}$（ｑ）と軟判定送信シンボルｂ′$_n$（ｋ）を用いて、ｎ番目の送信機の送信信号に対する干渉成分 $\mathbf{H}\cdot\mathbf{B}'$（ｋ）を計算し、
ここで
【数３】

$$\mathbf{H}=\begin{bmatrix}H(0)&\cdots H(Q-1)&&0\\&\ddots&&\ddots\\0&&H(0)&\cdots H(Q-1)\end{bmatrix}$$

$$H(q)=\begin{bmatrix}h_{11}(q)&\cdots&h_{1N}(q)\\\vdots&\ddots&\vdots\\h_{M1}(q)&\cdots&h_{MN}(q)\end{bmatrix}$$

$$\mathbf{B}'(k)=[\mathbf{b}'^T(k+Q-1)\cdots\mathbf{b}'^T(k)\cdots\mathbf{b}'^T(k-Q+1)]^T$$

$$\mathbf{b}'(k+q)=[b'_1(k+q)\ b'_2(k+q)\cdots b'_N(k+q)]^T$$

$q=Q-1\cdots\cdots-Q+1\quad q\neq0$ で

$$\mathbf{b}'(k)=[b'_1(k)\cdots\underline{-}f(b'_n(k))\cdots b'_N(k)]^T\quad q=0\text{で}$$

$\mathbf{b}'$（ｋ）の要素のｆ（ｂ′$_n$（ｋ））はｎ番目であり、ｆ（　）はｆ（０）＝０、かつｄ｛ｆ（ｂ′$_n$（ｋ）｝／ｄ｛ｂ′$_n$（ｋ）｝≧０を満たすｂ′$_n$（ｋ）を変数とする関数、［　］^{T}は転置行列であり、この干渉成分 $\mathbf{H}\cdot\mathbf{B}'$（ｋ）を受信ベクトル $\mathbf{y}$（ｋ）から差し引き差分ベクトル $\mathbf{y}'$（ｋ）を求め、
ここで $\mathbf{y}(k)=[\mathbf{r}^T(k+Q-1)\ \ \mathbf{r}^T(k+Q-2)\cdots\mathbf{r}^T(k)]^T$

$$\mathbf{r}(k)=[r_1(k)\ r_2(k)\cdots r_M(k)]^T$$

チャネル行列 $\mathbf{H}$ 又は参照信号を用いて、差分ベクトル $\mathbf{y}'$（ｋ）内の残余干渉成分を除去する、ｎ番目の送信機よりの送信信号の受信信号に対する適応フィルタ係数 $\mathbf{w}_n$（ｋ）を求め、
差分ベクトル $\mathbf{y}'$（ｋ）を上記適応フィルタ係数 $\mathbf{w}_n$（ｋ）によりフィルタ処理して、ｎ番目の送信機よりの送信信号に対する干渉除去された受信信号として対数尤度比を得ることを特徴とするターボ受信方法。
【手続補正３】
【補正対象書類名】明細書

【補正対象項目名】請求項４
【補正方法】変更
【補正内容】
【請求項４】　上記受信ベクトル $\mathbf{y}$（ｋ）中の雑音成分の共分散行列をＵとして、軟判定送信シンボルｂ′$_n$（ｋ）、上記チャネル行列 $\mathbf{H}$ を用いて、上記適応フィルタ $\mathbf{w}_n$（ｋ）を

$$\mathbf{w}_n(k)=(\mathbf{H}\,\mathbf{G}(k)\,\mathbf{H}^H+U)^{-1}\mathbf{h}$$

ここで、

$$\mathbf{G}(k)=\mathrm{diag}[\mathbf{D}(k+Q-1)\cdots\mathbf{D}(k)\cdots\mathbf{D}(k-Q+1)]$$

$$\mathbf{D}(k+q)=\mathrm{diag}[1-b'^2_1(k+q),\cdots,1-b'^2_n(k+q),\cdots,1-b'^2_N(k+q)]\quad q=Q-1\cdots-Q+1,\ q\neq0\text{で、}$$

$$=\mathrm{diag}[1-b'^2_1(k+q),\cdots,1-b'^2_{n-1}(k),1+2E[f(b'_n(k)]+E[f(b'_n(k)^2],1-b'^2_{n+1}(k),\cdots,1-b'^2_N(k+q)]\quad q=0\text{で}$$

Ｅ［　］は平均を表わす。
【数４】

$$\mathbf{H}=\begin{bmatrix}H(0)&\cdots H(Q-1)&&0\\&\ddots&&\ddots\\0&&H(0)&\cdots H(Q-1)\end{bmatrix}$$

$$H(q)=\begin{bmatrix}h_{11}(q)&\cdots&h_{1N}(q)\\\vdots&\ddots&\vdots\\h_{M1}(q)&\cdots&h_{MN}(q)\end{bmatrix}$$

$$\mathbf{h}=\begin{bmatrix}H_{1,(Q-1)\cdot N+n}\\H_{2,(Q-1)\cdot N+n}\\\vdots\\H_{M,(Q-1)\cdot N+n}\end{bmatrix}$$

$\mathbf{H}_{1,(Q-1)\cdot N+n}$ は上記行列 $\mathbf{H}$ の１行（Ｑ－１）Ｎ＋ｎ列成分により算出することを特徴とする請求項３記載のターボ受信方法。
【手続補正４】
【補正対象書類名】明細書
【補正対象項目名】請求項１０
【補正方法】変更
【補正内容】
【請求項１０】　２以上の整数Ｎ個の送信機からの信号を受信するターボ受信方法であって、
１以上の整数Ｍ個の受信信号 r_m と、既知信号とから、チャネル値 h_{mn}（ｑ）及びチャネル行列 $\mathbf{H}$ を計算し、
ここでｍ＝１，…，Ｍ、ｎ＝１，…，Ｎ、ｑ＝０，…，Ｑ－１、Ｑは各送信電波のマルチパスの数
Ｎ個の事前情報 λ_2［b_n（ｋ）］から軟判定送信シンボルｂ′$_n$（ｋ）を求め、ここでｋは離散的時刻、
チャネル値 h_{mn}（ｑ）と軟判定送信シンボルｂ′$_n$（ｋ）を用いて、ｎ番目の送信機の送信信号に対する干渉成分 $\mathbf{H}\cdot\mathbf{B}'$（ｋ）を計算し、
ここで
【数７】

$$\mathbf{B}'(k)=[\mathbf{b}'^T(k+Q-1)\cdots\mathbf{b}'^T(k)\cdots\mathbf{b}'^T(k-Q+1)]^T$$

$$\mathbf{b}'(k+q)=[b'_1(k+q)\,b'_2(k+q)\cdots b'_N(k+q)]^T$$

$$q=Q-1\cdots\cdots-Q+1\quad q\neq0\text{で}$$

$$\mathbf{b}'(k)=[b'_1(k)\cdots-f(b'_n(k))\cdots b'_N(k)]^T\ q=0\text{で}$$

$\mathbf{b}'$（ｋ）の要素のｆ（ｂ′$_n$（ｋ）はｎ番目であり、ｆ（　）はｆ（０）＝０、かつｄ｛ｆ（ｂ′$_n$（ｋ）｝／ｄ｛ｂ′$_n$（ｋ）｝≧０を満たすｂ′$_n$（ｋ）を変数とする関数、［　］^{T}は転置行列であり、この干渉成分 $\mathbf{H}\cdot\mathbf{B}'$（ｋ）を受信ベクトル $\mathbf{y}$（ｋ）から差し引き差分ベクトル $\mathbf{y}'$（ｋ）を求め、
ここで $\mathbf{y}(k)=[\mathbf{r}^T(k+Q-1)\ \mathbf{r}^T(k+Q-2)\cdots\mathbf{r}^T(k)]^T$

$\mathbf{r}(k)=[r_1(k)\ r_2(k)\cdots r_M(k)]^T$

受信ベクトル $\mathbf{y}$（ｋ）内の雑音成分の共分散行列を、ガウス分布の分散 σ^2 と単位行列 $\mathbf{I}$ から求まる $\sigma^2\mathbf{I}$ として、
【数８】

$$h=\begin{bmatrix} H_{1,(Q-1)\cdot N+n} \\ H_{2,(Q-1)\cdot N+n} \\ \vdots \\ H_{M\cdot Q,(Q-1)\cdot N+n} \end{bmatrix}$$

により決定した適応フィルタ係数 w_n により差分ベクトル y'（ｋ）をフィルタ処理して、ｎ番目の送信機よりの送信信号に対する干渉が除去された受信信号として対数尤度比を得ることを特徴とするターボ受信方法。

【手続補正５】
【補正対象書類名】明細書
【補正対象項目名】請求項２１
【補正方法】変更
【補正内容】

【請求項２１】　２以上の整数Ｎ個の送信機からの信号を受信するターボ受信機であって、
１以上の整数Ｍ個の受信信号 r_m を得る受信信号生成部と、ここでｍ＝１，…，ＭＮ個の復号器と、
各受信信号 r_m と、既知信号の参照信号とが入力され、チャネル値 h_{mn}（ｑ）及びチャネル行列 $\mathbf{H}$ を計算するチャネル推定器と、ここで
【数１２】

$$H=\begin{bmatrix} H(0) & \cdots H(Q-1) & & 0 \\ & \ddots & & \ddots \\ 0 & & H(0) & \cdots H(Q-1) \end{bmatrix}$$

$$H(q)=\begin{bmatrix} h_{11}(q) & \cdots & h_{1N}(q) \\ \vdots & \ddots & \vdots \\ h_{M1}(q) & \cdots & h_{MN}(q) \end{bmatrix}$$

ｎ＝１，…，Ｎ
各受信信号 r_m が入力されて受信ベクトル
y（ｋ）＝［r^T（ｋ＋Ｑ－１）　r^T（ｋ＋Ｑ－２）…r^T（ｋ）］^{T}
r（ｋ）＝［r_1（ｋ）　r_2（ｋ）…r_M（ｋ）］^{T}
ここでｋは離散的時刻、Ｑは各送信電波のマルチパスの数、ｑ＝０，…，Ｑ－１、［　］^{T} は転置行列を表わす、
を生成する受信ベクトル生成部と、
Ｎ個の事前情報が入力され、軟判定送信シンボル b'_n（ｋ）（ｎ＝１，…，Ｎ）を生成する軟判定シンボル生成部と、
各軟判定送信シンボル b'_1（ｋ）～b'_N（ｋ）が入力され、ｎ番目の送信機よりの送信信号に対する干渉レプリカベクトル
B'（ｋ）＝［b'^T（ｋ＋Ｑ－１）…b'^T（ｋ）…b'^T（ｋ－Ｑ＋１）］^{T}
b'（ｋ＋ｑ）＝［b'_1（ｋ＋ｑ）b'_2（ｋ＋ｑ）…b'_N（ｋ＋ｑ）］^{T}
ｑ＝Ｑ－１，…，－Ｑ＋１，　ｑ≠０で
b'（ｋ）＝［b'_1（ｋ）…$\underline{\ }$ｆ（b'_n（ｋ））…b'_N（ｋ）］^{T}ｑ＝０で
b'（ｋ）の要素のｆ（b'_n（ｋ））はｎ番目、ｆ（　）はｆ（０）＝０、かつｄ｛ｆ（b'_n（ｋ））｝／ｄ｛b'_n（ｋ）｝≧０を満す b'_n（ｋ）を変数とする関数であり、を生成するレプリカベクトル生成部と、
チャネル行列 $\mathbf{H}$ と干渉レプリカベクトル B'（ｋ）が入力され、ｎ番目の送信機よりの送信信号の受信信号に対する干渉成分 $\mathbf{H}\cdot B'$（ｋ）を計算して出力するフィルタ処理部と、
干渉成分 $\mathbf{H}\cdot B'$（ｋ）と受信ベクトル y（ｋ）が入力され、差分ベクトル y'（ｋ）＝y（ｋ）－$\mathbf{H}\cdot B'$（ｋ）を出力する差演算部と、
チャネル行列 $\mathbf{H}$ 又は参照信号が入力され、差分ベクトル y'（ｋ）内の残余干渉成分を除去するｎ番目の送信機よりの送信信号の受信信号に対する適応フィルタ係数 w_n（ｋ）を求めるフィルタ係数推定部と、
差分ベクトル y'（ｋ）と上記適応フィルタ係数 w_n（ｋ）が入力され、y'（ｋ）に対しフィルタ処理して、ｎ番目の送信機よりの送信信号に対する干渉除去された受信信号として対数尤度比を得てｎ番目の復号器へ供給する適応フィルタ部と、
を具備することを特徴とするターボ受信機。

【手続補正６】
【補正対象書類名】明細書
【補正対象項目名】００２２
【補正方法】変更
【補正内容】

【００２２】第２発明によれば、第１発明において、ｑ＝０の場合に、
b'（ｋ）＝［b'_1（ｋ）…$\underline{\ }$ｆ（b'_n（ｋ））…b'_N（ｋ）］^{T}
b'（ｋ）の要素のｆ（b'_n（ｋ））はｎ番目であり、ｆ（　）はｆ（０）＝０、かつｄ｛ｆ（b'_n（ｋ））｝／ｄ｛b'_n（ｋ）｝≧０を満たす b'_n（ｋ）を変数とする関数とすることを特徴とする。第３発明によれば、等化処理を複数段階に分けて行い、後段程、等化出力の系列の数を少なくする。

【手続補正７】
【補正対象書類名】明細書
【補正対象項目名】００５２
【補正方法】変更
【補正内容】

【００５２】式（２９）中の$b'(k)$、つまり式（３１）を次式に変更する。

$$\mathbf{b}'(k)=[b'_1(k)\ \ b'_2(k)\cdots b'_{n-1}(k)\ \ \underline{-f(b'_n(k))}\ \ b'_{n+1}(k)\cdots b'_N(k)] \qquad (43)$$

ただし、$f(b'_n(k))$は$b'_n(k)$を入力とする任意の関数

このようにすることにより、検出する信号$b_n(k)$に関しても誤り訂正復号結果を反映させることが可能となる。つまり$b'_n(k)=0$とすることなく$(b'_n(k))$に応じた適当な値を加算することにより、例えば、雑音や干渉信号に埋ずもれた検出する信号を強調することになって、$b_n(k)$を正しく検出することができる。

【手続補正８】

【補正対象書類名】明細書

【補正対象項目名】００５５

【補正方法】変更

【補正内容】

【００５５】$\underline{\mathbf{B}'(k)=[\mathbf{b}'(k+Q-1)\cdots\mathbf{b}'(k)\cdots\mathbf{b}'(k-Q+1)]^T}$

$\underline{\mathbf{b}'(k+q)=[b'_1(k+q)\ b'_2(k+q)\cdots b'_N(k+q)]^T}$　$\underline{q=Q-1,\cdots,-Q+1\ ,\ \ q\neq 0で}$

$\underline{\mathbf{b}'(k)=[b'_1(k)\cdots-f(b'_n(k))\cdots b'_N(k)]^T}$

<u>$q=0$で、$-f(b'_n(k))$は$\mathbf{b}'(k)$のn番目の要素</u>

【手続補正９】

【補正対象書類名】図面

【補正対象項目名】図９

【補正方法】変更

【補正内容】

【図９】

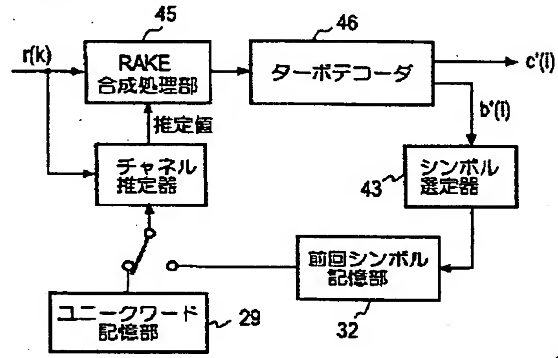


図9

【手続補正１０】

【補正対象書類名】図面

【補正対象項目名】図１９

【補正方法】変更

【補正内容】

【図１９】

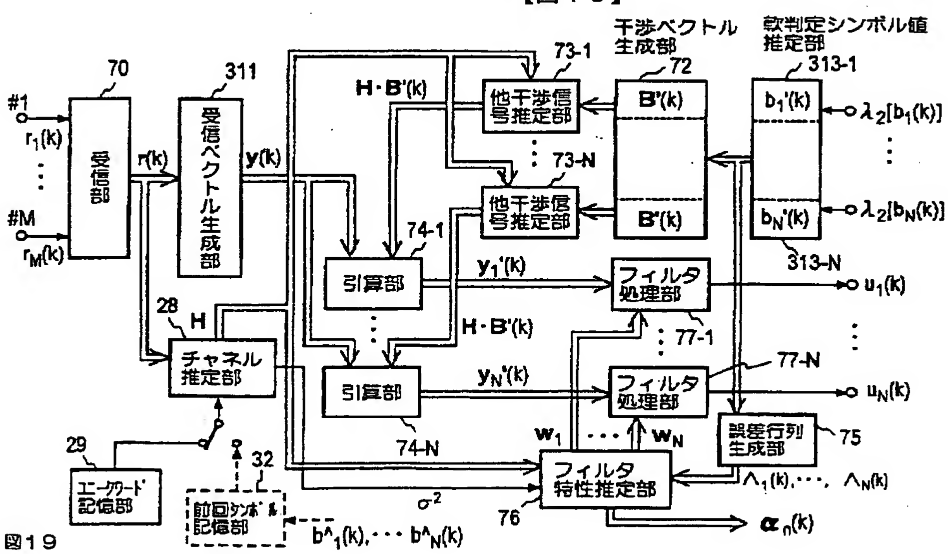


図１９

フロントページの続き

(72)発明者　冨里　繁
東京都千代田区永田町二丁目11番１号　株式会社エヌ・ティ・ティ・ドコモ内

(72)発明者　松本　正
東京都千代田区永田町二丁目11番１号　株式会社エヌ・ティ・ティ・ドコモ内

Ｆターム(参考)　5K014 AA01 BA10 EA01 FA16 HA10
5K022 EE01 EE14 EE31
5K046 AA05 EE06 EE19 EE47 EF13